Reconstructing and Interpreting Ancient Crop Management Practices:

Ethnobotanical Investigations into Traditional Dryland Farming in Northern Jordan

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Vol. I

Text

Thesis submitted in fulfilment of the Degree of Doctor of Philosophy

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September 1994

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Acknowledgements

This thesis owes its existence to the generosity, co-operation and assistance of a great many people. I feel very deeply privileged to have received so much of so many peoples' time and knowledge - all too many are too briefly mentioned here.

First, supervisors Glynis Jones and Paul Halstead deserve special thanks for inspiration, advice, and encouragement that I know was really much more than 'all part of the service' (P. Halstead, pers. comm.). They provided vital comments on earlier drafts of this work.

For their generous hospitality in Jordan, I am grateful to Fatma, Im Ra'id, Abu and Im Mahmoud. Esam esh-Shannag and family and Moraiwid and Ruth et-Tell and family, in particular, deserve special thanks. Esam esh-Shannag (University of Yarmouk), additionally, provided invaluable academic support and advice.

For assistance during field sampling, particular thanks are extended to Jad, Nasser, and Tha'ir. Sana' was at the core of 1992's fieldwork. I am also grateful to students from Yarmouk University and the staff at the Natural History Museum for their cheerful assistance.

Special thanks are extended to Andy Garrard and Alison McQuitty (both formerly of the British Institute at Amman for Archaeology and History) for enabling this project to be realised. Alison McQuitty provided some very practical and 'resucing' help and advice at critical points. Walid esh-Sharif started me on this very rewarding journey.

Thanks are also extended to Vartan Amadouny who provided an amazing range of references, and fascinating commentary, on the British Mandate in Transjordan. Nick Fieller provided statistical advice and Sarah O'Hara advice on the soil tests. Eugene Rogan kindly corrected the Arabic transliterations.

My parents deserve very special thanks for support and tolerance during the whole course of this venture, but most particularly for enabling its completion. My father prepared the figures for Chapter 6 and checked earlier drafts. Other PhD students at Sheffield provided vital support and encouragement; in particular, Louise, Sue, Karen, Jenny and the occupants of the 'Micro. lab.'.

The bulk of the research was funded by the Science and Engineering Research Council. Most of the fieldwork, however, would not have been possible without the financial support of the British Institute at Amman for Archaeology and History (BIAAH), the Wainwright Fund, the Robert Kiln Fund, and the Palestine Exploration Fund (PEF). The BIAAH was an invaluable base during my period of fieldwork in Jordan.

The support of the Department of Antiquities of Jordan, and of Dr. Ghazi Bisheh, former Director-General of Antiquities, is gratefully acknowledged. I am also particularly grateful to the University of Yarmouk for allowing me to use their herbarium facilities and conduct soil analyses in the Department of Geology and Earth Sciences.

I extremely grateful to the staff at the Royal Botanic Gardens at Edinburgh, and particularly Jennifer Lamond, for assistance with plant identifications. Sawsan and Daoud al-Eisawi also provided me with access to their excellent herbarium at the University of Jordan and helped with identifications. Prof. Sven Snogerup (Lund, Sweden) identified and commented on the *Bupleurum* spp. and Tom Cope (Kew) corrected the grass identifications.

I am indebted to the staff at ICARDA, Tel Hadya (Syria) for discussion, hospitality and a 'mountain' of pertinent literature. Thanks are also gratefully extended to the Jordanian Ministry of Agriculture and the Department of Meteorology as well as to the staff at Hunting Technical Services.

Finally, I perhaps owe the greatest debt to all the farmers of northern Jordan who took part in this study and generously gave of their time, knowledge and hospitality. I am extremely grateful for the way in which they treated my many questions with extreme patience and humour. They taught me a great deal.

This thesis is dedicated to the memory of Kenneth W. Russell whose life was tragically cut short in May 1992. Ken was a person of huge energy, contagious enthusiasm, and immense warmth. He possessed a deep respect for the people and archaeology of Jordan. I am enormously grateful to him for his support of this project.

Summary

This study is an exploration of agricultural decision-making and an investigation into the effects of different crop management practices on weed composition. The aim of this research is to enable the reconstruction of ancient crop management practices from archaeological weed assemblages and to inform archaeological interpretation, i.e. to interpret what the identified ancient crop management practices may imply. This particular investigation focuses on contemporary and recent 'traditional' farmers in northern Jordan.

The first aspect of this study looks at agricultural practice and agricultural decision-making. In order to sustain agricultural production farmers rotate their crops - typically with a period of bare, or cultivated, fallow. The choice of crop rotation regime (and indeed, how crops are managed during the agricultural year) is affected not only by environmental factors but also by cultural and social factors. For example, contemporary farmers who own livestock often cultivate legume crops rather than practice fallow between wheat years. On the other hand, short-falls in labour can result in the elimination of legumes from a crop rotation regime. In the past 60 years, the system of land tenure in the study area has profoundly changed - from communal to private ownership - and this also has affected crop management practices. The implications of these observations for archaeological interpretation are assessed.

The second aspect of this study examines the way different crop management practices affect weed composition. Although the main factor affecting weed composition was found to be vegetation zone, there was also some indication that crop management practices do indeed affect weed composition, but further substantiation is required. There is evidence that cultivated fallow favours the presence of weeds which can germinate in either autumn or spring whilst continuous cultivation encourages the establishment of perennial weeds. In both cases, tillage - the number of episodes and the timing of the operations - would seem to be the key factor. The way these results can be developed in the future are discussed.

Abbreviations

ADAJ	Annual of the Department of Antiquities of Jordan
FAO	Food and Agriculture Organisation, United Nations
HKJ	Hashemite Kindom of Jordan
ICARDA	International Centre for Agricultural Research in the Dry Areas, Syria
JCO	Jordan Co-Operative Organisation
JHADP	Jordan Highland Development Project
MAB	The UNESCO Programme on Man and the Biosphere
MOA	Ministry of Agriculture, Jordan
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

Notes

Currency

The unit of currency is the *Jordanian Dinar* (JD), also known locally as the lirā.

Between 1990-92: £1 = c. 1.04 JD
Between 1951-1959: £1 = 1 JD

Weights and Measures

The metric system is used (however, for 'local' weights see Table 5.3).

Land area is measured in *dunums* (1 dunum = 0.1 ha).

Transliteration

Transliteration follows the system outlined in ADAJ. Well-known place and area names, however, are written using the most commonly received transliteration (e.g. Irbid, 'Ajlun, Ramtha, Hauran). Transliterations are written in 'Romance' font (the standard font for the thesis is 'New York').

Nomenclature

Wild plant nomenclature follows *Flora Palaestina* (M. Zohary & Feinbrun-Dothan 1966-86) except where stated (see 4.2.4). Economic plant nomenclature follows Mabberly (1987) except for *Hordeum* spp. which follows Charles (1990) and *Sorghum* spp. which follows Uphof (1968).

Chapter 1 Introduction

This thesis explores the relationship between environment and culture (the natural and social environment). It is explored, specifically, in relation to agricultural practice and is analysed on two levels. The first looks at contemporary and recent farmers and the factors which influence them to farm in the way they do and the second, analyses weeds found in arable fields that are managed in different ways. The first level of analysis combines a simple decision-making analysis (looking at farmer's actions in terms of inputs and outputs) with a fuller exploration of the decision-making environment - and thereby also includes factors which cannot be measured easily. The analysis of crop weeds is a contribution to a larger programme of research, in the Department of Archaeology and Prehistory at the University of Sheffield, looking at the effects of different crop management practices on weed composition. The long-term aim of this research programme is to establish botanical criteria which will enable the identification of crop management practices (e.g. irrigation, garden-plot cultivation, fallowing) from the weeds found accompanying ancient crops.

The geographical focus of the inquiry is northern Jordan - an area with a typically Mediterranean climate and a long history of cultivation (indeed, it forms part of the so-called 'Fertile Crescent'). It was chosen because many farmers still operate there using traditional farming techniques and also practise a range of crop rotation regimes. Although the focus is northern Jordan, this investigation addresses a number of issues which are relevant to a number of current debates in archaeology, anthropology and indeed, rural development and therefore has broader applications. As well as exploring the relationship between environment and culture, this study looks at the role of ethnographic analogy in archaeology. It tries to emphasise the importance of history and tradition but at the same time explores why people change. It attempts to relate the 'small-scale' to the greater whole, or 'process'. Finally, this is also a document of 'traditional' farming practice - practices which are rapidly disappearing.

The crop management technique at the centre of this exploration is cultivated fallow. It was chosen because it is a traditional technique used to cope with drought, fertility problems and to control weeds but also because it ties in with particular cultural phenomena, for example, tillage technology, labour and land availability. This will be explored in greater detail below.

1.1 Cultivated Fallow

Cultivated fallow is one of the traditional dominant features of Mediterranean arable farming. A cereal-fallow rotation regime is the most common regime practised in the region. The most popular explanation for the prevalence of the technique is that it allows soil moisture to be restored - moisture availability being the critical limiting factor on agricultural production. Recently, this assumption has been challenged by agronomists who have suggested that cereal-legume rotation and continuous cereal cropping with the addition of fertilisers/manure are viable alternatives to cultivated fallow, especially in the long-term. This suggests, by implication, that moisture is not the only constraining variable on agricultural production. It also raises the question as to whether fallow was always a constant of Mediterranean agriculture (Halstead 1987, 81-83).

Cultivated fallow has been linked to a particular agrarian system where technology (plough teams), labour availability, land availability, settlement nucleation (and distance from the fields), and grazing requirements are vital (Halstead 1987). It is also a system which reduces weed growth and seems to have ensured a certain level of production - albeit a low one (Harris 1990). This also leads to a key point - cultivated fallow is synonymous with extensive agricultural systems. In extensive systems, production is increased by cultivating larger areas, i.e. production per unit area is comparatively low (i.e. scale of production is important). Practices which increase production from any given area such as irrigation, manuring, or continuous cultivation are often classified as intensive (see Halstead 1992a, 109-110 for discussion of different interpretations of 'intensification'). Plough agriculture and irrigation agriculture have also been termed 'advanced' techniques (and also confusingly 'intensive') and linked with broad aspects of human society (economic, political and kinship systems) by Goody (1976). He linked advanced agriculture with 'diverging devolution' - where property is not retained within the unilineal descent group, but is distributed to children of both sexes and hence outside the clan or lineage (Goody 1976, 7). Plough (and Goody's 'intensive') agriculture is also considered to allow for expansions in population and is additionally, linked with monogamy, large estates and complex systems of stratification (Goody 1976). It can be seen, therefore, that cultivated fallow, is not simply a technique used to store moisture but also one which has implications/ramifications for much broader aspects of society.

In this thesis, cultivated fallow is explored; to assess its 'real' benefit to soil moisture and fertility and under what conditions it is practised in northern Jordan. The second aim of the thesis is to try to identify weeds, or rather the ecological characteristics of weeds, which are associated with different crop rotation regimes.

1.2 Ethnographic Analogy and Archaeology

Analogy underlies all archaeological reconstruction and interpretation - 'archaeology is based on analogy' (Hodder 1982, 9). Analogy is used in identifying a carbonised grain as emmer wheat, in referring to an object as a 'cooking pot', interpreting a site as a 'base camp', deriving social structure from art, or in attributing sudden settlement abandonment in a region to famine. The origins of our analogies rest in our contemporary lives and in the ethnographic record. Archaeologists observing human behaviour - practising ethnography - for specific archaeological aims are involved in ethnoarchaeology. Ethnoarchaeologists attempt to determine how human activity is reflected in the archaeological record. They also compare spoken behaviour to observed behaviour (Hodder 1982, 46).

There are, in very simplified terms, two different levels of analogy. Whilst these two levels have been given various names in the literature, they shall be referred to here as analogies which are used to reconstruct the past (identify human activity) and analogies which seek to interpret change in the past (interpret human behaviour).

1.2.1 Reconstructing the Past

The first level of analogy uses mechanical things, things considered as independent of human behaviour, to infer human activity. One of the most successful applications of this reconstructive approach within archaeobotany has been the archaeological identification of crop processing stages by the physical characteristics of weed species growing with crops (Hillman 1981; 1984; G. Jones 1984; 1987). The main stages in the crop processing sequence following reaping are: threshing - to release the grain from chaff and seeds from pods; winnowing - to remove the chaff and straw; coarse sieving - which allows the grain to pass through the sieve leaving large straw fragments, large weed heads and unthreshed ears; fine sieving - where the grain is retained in the sieve and small weed seeds pass through; and finally, hand-picking - for the removal of weeds whose characteristics are similar to the grain. Although the implements used vary slightly in different ethnohistoric accounts, the processing stages remain essentially the same as do their effects on composition of the products and by-products (G. Jones 1983a, 19-20). This information has been successfully used to identify crop processing stages in ancient material. The important factor in this type of analogy is that present human behaviour is linked to past human behaviour via an independent medium - in the example given, this is the aerodynamic quality and size of weed species. Uniformitarian assumptions about the way people behave are, therefore, avoided (G. Jones 1983a, 20). This type of analogy broadly correlates with 'middle range research' (Binford 1977; 1981).

1.2.2 Cultivated Fallow and Weed Behaviour

Part of the aim of this thesis is to establish criteria which will allow for the identification of cultivated fallow in the archaeological record (via weeds recovered alongside ancient grain assemblages). Conversely, the identification of continuous cropping (e.g. cereal-legume cropping) through weeds found with crops would help to identify 'intensification'. The independent medium through which it may be possible to identify cultivated fallow is the ecological preference and physiological characteristics of different weed species. Weeds are highly responsive to varying growing conditions and these growing conditions include both 'environmental' (for example, climate and soil) and 'cultural' factors (such as fallow, irrigation, tillage methods, manuring etc.). This aspect of the research is very much inspired by the work of G. Jones who is currently investigating the effects of garden-plot type management and irrigation on weed composition (G. Jones 1992; G. Jones *et al.* in press). This aspect, therefore, is part of a broad and long-term programme of investigation. In this type of research, ethnoarchaeology is used as a means of generating a middle range methodology for the interpretation of archaeological plant remains (Hillman 1973a, 241; G. Jones 1983a, 17).

1.2.3 Interpreting Change in the Past

The second type of analogy, termed here interpretative analogies, are more difficult and less directly linked to the fragmentary archaeological record. It is necessary, however, for archaeologists to interpret their findings and develop explanations for a broad range of archaeological problems but this use of analogy is not independent in the same way as analogies that are used for reconstructing the past. In this second type, present human behaviour is used more-or-less directly to explain past human behaviour so that, for example, it is possible to discuss the symbolism of art or suggest the 'structure' of a past society. Furthermore, and for example, archaeologists have speculated on past population levels in a particular region using plough technology (Hillman 1973b), the role of risk and surplus (Halstead and O'Shea 1989), and on the ideological division between the domesticated and wild realms (Hodder 1990) - all using ethnographic analogies. Despite the fragmentary nature of the archaeological record, archaeologists do possess the ability to look at change through time - it is possible to speculate on the causes, mechanics and ramifications of a particular phenomenon and trace its 'progress' through time. Interpretative analogies are perhaps synonymous with 'general theory' and have been used since the earliest interpretations of archaeological discoveries. The decision-making aspect of this thesis is inspired by research which has challenged archaeological assumptions and prompted new lines of questioning using analogues from contemporary 'traditional' rural societies (e.g, Forbes 1982; Halstead 1987; Halstead and O'Shea 1989; Halstead 1992a & b; Whitelaw 1991).

1.2.4 Cultivated Fallow and Human Behaviour

The link between cultivated fallow and plough technology, labour availability, and social organisation has been discussed in 1.1. Moreover, part of the aim of this thesis is to explore further the factors which affect the adoption of a particular crop rotation regime. It is hoped that the identification of cultivated fallow (or other cropping strategy) in the past via ancient and modern weeds will provide important insights on other realms of past human behaviour.

1.2.5 Conclusions - Reconstruction and Interpretation

Ultimately, by comparing the ecological preferences of contemporary weeds with known management backgrounds, with the weeds found accompanying ancient cereals it should be possible to identify past crop management. As the characteristics of the weed species are the important factor, rather than the weed species themselves, this information can be applied to assemblages recovered from all around the Mediterranean basin. The final link will then be to use the information recovered concerning the cultural and environmental factors which influence agricultural practice to interpret what may have been 'going on' behind the detected crop management practices.

The boundary between reconstructive and interpretative analogies is blurred - depending upon what is considered to be an independent variable by the analyst (also cf. the continuum of variation between 'formal' and relational' analogies discussed by Hodder (1982, 16)). The division, however is useful - the development of middle range research does have some utility as a framework for the critical examination of some problems of archaeological method (G. Jones 1983a, 17). The way both reconstructive and interpretative analogies are investigated in this thesis also acknowledges that similarity in one aspect between the past and present does not necessarily mean that similarities exist in other realms (Binford 1981, 27-8; Hodder 1982, 12-14).

1.3 The Study Area

The study area is situated in the north-west corner of modern Jordan (Fig. 1.1). It stretches from the Yarmouk river in the north to 'Ajlun in the south and from the upper slopes of the Jordan Valley in the west across to Ramtha (Wadi Shelaleh) in the east and can be divided into 'hill' and 'plains' zones. The flatter land constituting the plains zone lies in the north and east of the study area. The hills zone consists of the land that, to the north, descends rapidly westwards from the plains to the Jordan Valley and, to the south-west, rises up to the massif around 'Ajlun before plunging down again to the Jordan Valley. The hills zone stretches across the entire southern limits of the study area. The study area, and the plains in particular, produce the highest dry-farmed grain yields in Jordan.

The study area was chosen because:

1. It has a Mediterranean climate - it is, therefore, possible to explore the way farmers respond to the uncertainties of a Mediterranean climate (one of the key 'adaptations' being cultivated fallow).

2. A range of crop rotation regimes are practised in the study area and cultivated fallow is a prominent component of most regimes. In general, two-year crop rotation regimes are practised in the hills and three-year regimes on the plains.

3. Crops are still managed by farmers who use limited amounts of modern technology. Especially in the hills, animal drawn tillage is still used and comparatively few small-scale farmers use chemical weed killers. Many farmers still cultivate crops which are primarily for household consumption.

4. The area is internally diverse both in terms of environment (topography, climate and soils), culture and history. There was, for example, a different system in the way agricultural land was reallocated between hills and plains villagers. The plains, in particular, according to local tradition have experienced more settlement in the last 150 years or so. The hills and plains zones will be discussed further below.

Many aspects of 'traditional' life persist in the hills, although they have disappeared from the plains. The continuation of these practices suggests the persistence of a lifestyle where a high proportion of household consumption is supplied by the household itself. The old style clay oven (ṭābūn), for example, is still commonly used to bake bread and many families still prepare their own milk products. For the plains villages, women either bake their bread using gas fired ovens or purchase it from one of the many commercial bakeries that have been established in recent years. Most families, whilst preferring home-produced goods, in practice purchase milk products commercially and have sold their milk producing animals (frequently within the last five to ten years).

Both the hills and plains villages are closely linked to the administrative centre of Irbid but the plains villages particularly so. Irbid not only provides waged employment for villagers who commute there on a daily basis but the town also attracts large numbers of seasonal workers, many from Syria and Egypt, who are hired by the day at times of agricultural stress (principally during sowing and harvest). In addition, Irbid has a large and thriving market in which a large range of provisions can be bought and sold. Despite the greater distance, people living in the hills do have comparatively easy and cheap access to Irbid through the many locally operated buses (if, of course, they do not have access to private transportation). In the vicinity of Irbid, there is a large agricultural centre operated by the Jordan Co-operative Organisation (JCO), so assistance with improved agricultural technology (machines, agro-chemicals and improved crop varieties) is fairly readily available.

On the plains, the land is generally flat and therefore, accessible to modern machinery such as tractors, herbicide and pesticide spray tanks and combine harvesters. Whilst the traditional ard, or scratch-plough, is still used, it is usually confined to tillage beneath trees and between summer crops. In the hills, fields are often located on remote and steep hillsides and therefore, can only be tilled using animal traction. Donkeys are the principal form of dual animal traction.

In the higher altitude of the hills area where the climate is comparatively cooler, many episodes in the agricultural cycle, for example, the planting of legume crops and the harvesting of wheat, take place at a later date than on the plains. The time lag concerned may vary between a few days to two or even three weeks.

In sum, the study area was chosen for its diversity, long history of cultivation and the persistence of traditional forms of crop management. The villages mentioned in the text are shown in Fig. 1.2. A glossary of local Arabic words used in the text is given in Appendix 1.1. The study area was also chosen because of the people there - people who were exceptionally hospitable, good humoured and above all patient with an independent female researcher who had a curious interest in 'old-fashioned' farming methods and weeds.

1.4 The People - Fellaheen, Peasants, or Farmers?

'Fellaheen' (translit. fallāḥīn), the Arabic name for the farming population of the Middle East, is derived from the word falaḥa to 'cultivate' thus making the fellaheen 'cultivators' (cf. Fuller 1961, 73). The word fellaheen is, however, frequently translated as 'peasants' - a word that has a particular social connotation of subjugation (Mintz 1974, 94; Woolf 1966, 13). Indeed, the fellaheen themselves depict their history as a group burdened by taxes and brutalised by bedouin raids and the extortions of the bedouin tribute (the khuwa), a picture which appears to conform to the general assumption of subjugation. Peasants are usually viewed as a 'part' society dependent on the state, urban society and/or pastoral nomads.

In much of the anthropological literature, the terms farmer and peasant have been used interchangeably (see Forbes 1989, 89). The term peasant does, however, have certain disadvantages with its frequent uncomplimentary usage and notions of timelessness and stasis. This is particularly unfortunate in the Middle East where anthropological inquiry was for a long time framed in a functionalist-orientalist paradigm (Eickelman 1981, 45-62; Glavanis and Glavanis 1989, 3-7). This approach sees rural life as essentially static with change principally coming from outside (cf. the Asiatic Mode of Production). In the archaeological literature, the term peasant seems to be largely ignored and yet, so many analogues, usually interpreted using an agrarian ecological paradigm, clearly use explanations supplied by the recent and contemporary study of what are/were peasants. The avoidance of the term is perhaps justified as archaeologists wish to avoid the complex social connotations of the term (feudalism etc.) and the restriction to a particular historical period. Instead, terms such as 'subsistence' and 'small-scale' are preferred. And yet, in concentrating on the ecological adaptations of rural life, the social dynamic is underrated.

In this study, the term 'farmer' has been adopted to indicate a person who farms and has some control over agricultural decisions. It has been chosen to avoid some of the connotations noted above and to be closer to the notion of a 'cultivator'. Where the Arabic term 'fellaheen' (sing. 'fellah', fallāḥ) is used, it is used either historically (e.g. see 2.6) or in the specific sense of people originating from the study area involved with crop management for all their working lives largely using 'traditional' techniques.

The term farmer, on the other hand, does seem to imply a complex set of social and economic relations and implies a high degree of commercialisation and integration into a market economy that is not entirely justified. These factors have led scholars working in rural development and sociology to prefer the term peasant but to search for a new definition, first, to present a more accurate description of this group and secondly, to create a theoretical and more flexible meaning. The farmers discussed in this study do broadly conform to current definitions of peasantry, for example:

> Peasants are farm households, with access to their means of livelihood in land, utilising mainly family labour in farm production, always located in a larger economic system, but fundamentally characterised by partial engagement in markets which tend to function with a high degree of imperfection.
>
> Ellis 1988, 12

There are some problems with the term household which will be considered below. This definition, however, emphasises one of the main factors emanating from studies of contemporary peasants which is that non-capitalist relations and forms of production have persisted in Middle Eastern rural society despite the expansion of capitalism (Glavanis and Glavanis 1983, 2). Much of the contemporary development literature concentrates on trying to fit 'peasant economies' into some kind of neo-classical economic model so that development policies can be formulated and applied. Rural sociologists, on the other hand, seem to be concentrating on how capitalism affects, or why it does not affect, rural producers - the forms and relations of production (e.g.

Glavanis and Glavanis 1983; 1989). The conclusion invariably is that rural farmers/peasants (not only in the Middle East) cannot simply be defined as 'simple commodity producers' (see Friedmann 1980), but operate on a number of levels (household economies, risk aversion, drudgery aversion) whilst at the same time integrating with the market and government policies. The history of a particular area is also increasingly viewed as important (e.g. Keyder 1983; Keyder and Tabak 1991) and rural transformations have been viewed as key to understanding contemporary political structures in the Middle East (Gerber 1987).

1.5 Analytical Approach

The two approaches used in this thesis - ethnographic and botanical - are described in this section. It is perhaps particularly important to establish the theoretical stance of the ethnographic approach as there are potentially greater theoretical problems in this domain. This is not to say, however, that the botanical approach does not require further elaboration.

1.5.1 Ethnographic Approach - Decision-Making

Decision-making as a method to appraise or predict human response to scarce resources is well known in development economics and rural sociology. Specifically from the 'economic' standpoint, it recognises that each decision taken by a farmer (or group of farmers) involves a cost-benefit type analysis. Since the early applications of this type of approach, it has received many interpretations and amendments depending upon the theoretical standpoint of the author (e.g. Marxist or capitalist approaches) or the time depth of the analysis. More often, however, the models have required adjustment because human action cannot be simply explained in terms of an equation of input and output, motives also have to be assessed. Anthropological studies of human responses to concepts such as risk and economy as a part of social life have helped to understand why the classic models failed to explain so many human actions.

Most criticism of decision-making analyses has concentrated on their highly specific nature and therefore, their inability to explain change on a broader basis (Apthorpe 1977 in Harriss 1982, 21). One farmer may choose to grow a certain crop for one set of reasons whereas another farmer/group may invest in a different set of options. This, however, overlooks the fact that in seeking to understand why decisions are taken, human action is broken down into component parts which do in themselves have general application. In terms of archaeology, the isolation of these domains, e.g. technology, labour availability, animal husbandry, land tenure, etc. means that farming practice can be integrated into many other domains of evidence - from settlement patterns to the study of animal bones. This theme will be explored further in chapter 8. Decision-making analyses also acknowledge that change can originate from 'inside' a society and not primarily from 'outside' (e.g. Boserup 1965; Geertz 1963).

In this study, the 'decision-making' farmer and the household (the residential unit and unit of consumption) are taken as the economic unit and form the basis of the analysis. There are, however, acknowledged problems with this approach - it somewhat underplays the division of labour within the household and the life-cycle of the household (number, age and sex of household members through time). It also ignores relationships between households. For example, kinship alliances in the study area were formerly very important for agriculture, particularly under the old system of land tenure, and many agricultural operations were undertaken together. Since the break-up of communal land tenure, kinship ties are less strong and the 'economic unit' is closer to the household (cf. Antoun 1972, 75-6). Households may, however, operate joint budgets where land is held in common or households have recently divided (Taminian 1990, 21) and draw upon relatives' support at particular times. In addition to the decision-making analysis, therefore, these 'social relations' will be discussed in the text where appropriate.

Finally, in this thesis, the factors which influence farmers' decisions are viewed as opportunities and constraints enabling and limiting change - rather than as determining factors. In this way, the often created/quoted polarity between environmental and social factors is avoided. It is also, moreover, an attempt to reflect the true complexity of ongoing systems (cf. Whitelaw 1991, 452).

1.5.2 Botanical Approach

There are two main debates in regard to the botanical approach. The first concerns the longevity of the ecological characteristics of weed species and the second, concerns the use of multivariate analyses - and specifically, ordination.

To facilitate the reconstruction of ancient crop mangement, the physiological and ecological characteristics of weeds are viewed as the intermediaries between the present and the past and the means by which it may be possible to identify past crop management practices. There is an apparent problem, however, in that the present-day ecology of many weed species is very variable and also that temporal changes in the ecological attributes of some species may have occurred. This problem is discussed by G. Jones (1992, 136-7) and summarised here. As Jones points out, by definition, arable weeds (segetals) cannot have existed prior to cultivation and since then, many have evolved a close adaptation to the crops with which they are grown. In addition, agricultural innovations may also have resulted in further evolutionary change as well as favouring some species over others (G. Jones 1992, 136). For example, in Britain archaeological evidence suggests that *Sieglingia decumbens* (L.) Bernh. was an arable weed prior to the introduction of the mouldboard plough (Hillman 1981, 146). Today, it is usually found in poor grassland situations (Hubbard 1984). More recently, herbicides have eliminated some weed species, but enabled others to colonise new habitats in which they were previously unable to compete (Holzner 1978, 17). In the past, species will have competed against each other - increased or decreased in number, been introduced or driven out completely (cf. M. K. Jones 1988). 'Obviously, these changes within species, in physiology or ability to compete, pose problems for the identification of crop husbandry practices' (G. Jones 1992, 136).

It is largely because of this problem that it is necessary to examine the behaviour of groups of weeds rather than look for potential 'indicator' species. In any case, the available evidence suggests that arable weeds which are precise indicators of specific conditions (e.g. soil acidity) are rare (G. Jones 1992, 136; Lange 1990, 40). So, it is preferable to look at groupings, or perhaps consider plant 'communities', and the ecological conditions favourable to the group. One possible approach is to use phytosociology. Phytosociology is the study of plant communities (Braun-Blanquet 1964) and has a widespread following in Europe (Ellenberg 1950; 1979; Tüxen 1950). Phytosociology defines plant communities by their floristic composition, although it also considers the ecological conditions of the community. It is an hierarchical system with associations as the basic unit and alliances, orders and classes as higher units. Each syntaxon is characterised by species which have different degrees of 'fidelity' ranging from high ('character species') to low ('constant companions').

There are, however, two problems associated with the use of phytosociology in archaeology: the first lies in the stability of the syntaxa through time and the second, concerns the nature of archaeobotanical samples. A number of researchers have questioned the stability of plant associations through time (e.g. Holzner 1978; Behre and Jacomet 1991; M. K. Jones 1984; Hillman 1991), although it is considered that there is likely to be more stability in the higher classifications (G. Jones 1992, 136-137). Concerning the second problem, there has been extensive discussion and research surrounding the origin, nature and taphonomy of archaeobotanical samples (e.g. Boardman and Jones 1990; Hillman 1981; 1984; 1991; G. Jones 1984; 1987; Lange 1990, 40-41). Briefly, archaeobotanical samples derive from diverse origins - spatially (e.g. the harvest from different fields may be processed together), contextually (e.g. pits, hearths, floors, etc.), and temporally; may represent different stages of the crop-processing sequence (and, of course, not all weeds are included with the harvested crop); may be differentially preserved or recovered; and finally, may be mixed with material from a non-arable origin. They cannot, in sum, be considered as representative of whole individual plant communities (G. Jones 1992, 141). Consequently, it is important to attempt to compare like with like (e.g. samples which represent fine-sievings with other samples which represent fine-sieving (Dennell 1974, 283-284; G. Jones 1992, 141). Additionally, it has also been forcibly argued that groupings should be analysed based upon the association of the intrinsic characteristics of individual samples and species rather than using extrinsic classifications such as phase or context type (at first at least) (see Lange 1990, 40-41).

Multivariate analysis, and specifically the ordination technique correspondence analysis (CA) (see 4.4), was chosen because it allows intrinsic characteristics of the modern data to be explored, i.e. it allows patterns to be detected without predetermining what those patterns should be (Lange 1990, 40-41). The patterns can then be interpreted in the light of what is known about the samples (or, as in this study, the fields) and species. This is complemented by the use of canonical correspondence analysis (CCA) which permits known variables (e.g. crop rotation regime) to be included in the analysis. Using this method, the ecological and physiological characteristics of weeds are the focus (the linking factors) rather than the particular species. In other words, the groupings of species are used to indicate the presence of ecological conditions favourable to the group as a whole rather than to identify a community (cf. G. Jones 1992, 136-137).

1.5.3 Structure and Orientation of the Thesis

The thesis begins with a description of the 'natural' and social environment of northern Jordan. The pairing together of the 'natural' and the 'human' in this chapter is done to emphasise that not only rainfall, temperature and soils etc. constrain agricultural production but also the local political and economic position. The history of the study area is also vitally important for an understanding of contemporary local conditions. This is followed by an exploration of the agronomic literature, first, to assess the ability of cultivated fallow to restore soil moisture and fertility and secondly, to assess the advantages and disadvantages of replacing fallow with continuous cultivation. The ethnographic, ecological and statistical methods used in this thesis are outlined in chapter 4.

In the next two chapters the ethnographic results are presented. In chapter 5, the local 'decision-making environment' is described. The aim of this chapter is to set out the nature of farming in the study area: the crops cultivated, farming equipment, animals held, and the year-to-year cycle of events. In chapter 6, the people themselves are placed at the centre of the discussion and the focus is on the crop management decisions taken by farmers - decisions which operate above and beyond the environmental limitations of the Mediterranean climate. This chapter also considers the way crop management practices have changed during this century - and the reasons behind the changes.

Crop management practices and weed ecology are explored in chapter 7. The relationship between weed ecology and natural (environmental) and cultural (crop management) factors is explored using correspondence analysis (CA) and canonical correspondence analysis (CCA). The behaviour of individual taxa in relation to some of their known physiological characteristics is also explored.

Finally, in the concluding chapter, the two aspects of the thesis are brought together: reconstructing and interpreting ancient crop management practices.

Chapter 2 Environmental and Social Setting

> 'one could hardly see in any country a more delightful region through which to travel ... here are old forests. The oaks are covered with moss, birds abound in the trees ... The views to the west of the Jordan Valley and the mountains beyond, of Jebel Sheikh directly before us in the north, gleaming in the sun, and to the east of the ancient Bashan plain, are wide and magnificent, and the wheat fields and other marks of fertility everywhere make me forget that I am in poverty-stricken Palestine.'
>
> Merrill 1881, 292

In this chapter the 'natural' and 'social' environment of northern Jordan is outlined. The climate, topography, geology, soils and vegetation of the study area all demonstrate the essentially Mediterranean character of the area. The study area, however, also lies at the periphery of the cultivable zone. The social environment is considered largely in relation to the last 100 years of human experience. The farming population (the fellaheen) have demonstrated considerable flexibility in their response to major institutional and economic change.

2.1 Topography

The study area is included in a region of Jordan often referred to as the 'Northern Highlands' and consists of a plateau edge overlooking the Jordan Rift Valley (Beaumont 1985, 291). The study area is dissected by five deep and impressive wadis including the Wadi Yarmouk in the north and the Wadi Kufrinjah to the south (Fig. 2.1). These wadis follow extremely long westward descending courses which drop rapidly, particularly in their lower sections, to the Jordan Valley. The dissected nature of the region means that the very steepest slopes are concentrated in the west and that slopes between 15% and 40% are not uncommon (Beaumont 1985, 291). These lower sections, however, lie beyond the limits of the study area as the land is generally too steep for cultivation.

As has been outlined in chapter 1, the study area can be usefully divided into hills and plains zones (Fig. 1.1). The plains zone lies in the north and east of the study region across an altitude ranging between 500 and 600 m above sea level. To the south-west of the hills zone the land rises up to an altitude of 1198 m above sea level in the vicinity of 'Ajlun (Fig. 2.1 and close to Rās Munief).

The land system classification defined by Mitchell and Howard for Jordan (1978) uses relief as one of the main criteria for defining the different land units. The plains zone of the study area largely corresponds with the 'Irbid plain' (Mitchell & Howard 1978, 77) (Fig. 2.2a), although it also slightly intrudes into the 'basalt plateau' (Mitchell & Howard 1978, 86-87). The principal land unit which corresponds with the hills zone is the 'high upland on 'Ajlun limestone' (Mitchell & Howard 1978, 47) (Fig 2.2b), although once again, there are also other units which define areas that are dissected by major wadis and also have slightly different geology (see below). The 'Irbid plain' and 'high upland' units as defined by Howard and Mitchell illustrate well the main topographic features which distinguish the hills from the plains. In the hills cultivation is situated in patches on the summits, slopes and wadi floors of the area between forest, scrub and scree. The virtually uninterrupted nature of the plains, on the other hand, allows for almost continuous cultivation.

2.2 Climate

The north-western corner of Jordan has a characteristically Mediterranean climate. The primary feature of this type of climate and the principal factor which separates it from all others is the alternation of a rainy season in the cold months with a dry season in the warm months (Tomaselli 1977, 35). For the calendar year as a whole potential evaporation exceeds total precipitation and the Mediterranean is, therefore, termed a precipitation deficit region (FAO-UNESCO 1974) or, alternatively, a xeric moisture regime. The pronounced summer dryness, where drought coincides with the thermal maximum, is a factor which is not only reflected in specific agricultural practices, but also, on a broader level, shapes the region's vegetation and gives it one of its principal characteristics - its adaptation to aridity (Nahal 1981, 82).

Bioclimatically, the region under survey is divided into sub-humid and slightly warmer semi-arid Mediterranean zones with its fringes in the arid Mediterranean zone (al-Eisawi 1985, 49). The majority of the area, however, lies in the semi-arid zone. Figs. 2.3a-d show average monthly temperature and precipitation levels for four of the area's meteorological stations (see Figs. 1.2 & 2.1 for location of the stations) with medium-term records and graphically illustrate the way in which cool wet winter months alternate with summer aridity. Irbid and Ramtha stations are situated on the plains and Rās Munief and Ṭaiyiba in the hills. The stations at Irbid and Ramtha are situated at similar altitudes (616 m and 590 m above sea level respectively) but Rās Munief and Ṭayiba are separated by almost 800 m (1150 m and 373 m above sea level respectively). According to figures calculated by Long (1957, 5-9) and al-Eisawi (1985, 46-50) using Emberger's (1955) precipitation and temperature quotient, Rās Munief (near 'Ajlun) has a sub-humid Mediterranean bioclimate whereas Irbid and Ṭaiyiba, being slightly hotter and drier, fall in the semi-arid Mediterranean zone. Ramtha, the most easterly station, has an arid bioclimate.

Details of the two main components, precipitation and temperature, that combine to define the bioclimatic zones are outlined below.

2.2.1 Precipitation

The area around 'Ajlun enjoys the second highest level of precipitation in Jordan (al-Eisawi 1985, 47). The average annual precipitation at Rās Munief (near 'Ajlun) is almost 550 mm (15 year average: 1976-1990). The north-western section of the study region, in addition, is directly exposed to the Mediterranean Sea and is consequently comparatively well-watered (Shehadeh 1985, 30). Irbid also has comparatively high precipitation although by the time Ramtha is reached, only 15 km east of Irbid, average annual precipitation drops dramatically to 221 mm (1976-87) - a figure just within the limits for cereal cultivation. The majority of the region, however, receives an average annual precipitation which potentially allows for complex crop rotations i.e. above 400 mm (Arnon 1972b, 28).

The average annual precipitation figures camouflage a high degree of variability in precipitation from year to year. Indeed, a major characteristic of Mediterranean and semi-arid climates is severe regional and local annual variation in rainfall (Bailey 1979, 91). Whilst the time periods concerned are comparatively short, Figs. 2.4a and b illustrate the variation in precipitation recorded at the meteorological stations at Irbid (on the plains) and Rās Munief (in the hills). As a general rule, areas with greater average annual precipitation suffer less from high levels of precipitation variability but it should still be stressed that severe perturbations do exist. Even though Irbid, for example, receives comparatively 'good' precipitation (compared to the rest of Jordan), the probability of receiving below 300 mm is 21%, i.e. one year in five the wheat crop will fail (Qasem & Mitchell 1986, 38). The annual variation in precipitation is a primary factor in agricultural uncertainty for dryland farmers and a perennial challenge to agricultural communities in the area.

In addition to year-to-year variations, runs of drought years do occur as, for example, between 1924 and 1936 when consistently low precipitation levels were recorded in Transjordan (Amadouny 1993, 90). This period is vividly remembered, and described, by the study area's older inhabitants. Records from Jerusalem (less than 100 km from the study region) which date back to 1851 illustrate how variation in total precipitation can be quite extreme (Russell 1988, 68-69). Fig. 2.5 illustrates very clearly how the fluctuation in precipitation translates into variations in wheat yield for the Kingdom of Jordan between 1955 and 1975.

Late rains are frequently associated with low pressure fronts called 'khamsine depressions'. These originate in the Atlas mountains and move along the southern shores of the Mediterranean, usually arriving in Jordan during springtime. The rain accompanying these episodes of low pressure is very important for summer crops and, on average, they account for 8% of annual precipitation (Shehadeh 1985, 30). 'Khamsine weather' is also characterised by strong winds and these winds pose a considerable threat to the ripening cereal crop.

During the 1991-92 winter, Jordan received the highest level of rainfall for 40 years - enough to raise the level of the Dead Sea by 0.5m (E. esh-Shannag pers. comm.). Additionally, a high proportion of this precipitation fell as snow. Snow, however, is not a prominent feature of the area's winter, although not entirely unusual - particularly in the higher altitudes. Rās Munief, for example, averaged 7.8 days with snow each year between 1976 and 1987 and, even on the plains, Irbid averaged 1.3 days with snow between 1961 and 1987 (Jordan Climatological Data Handbook 1988, 37).

2.2.2 Temperature

Average minimum, maximum and mean monthly air temperatures for the study area's four meteorological stations are given in Fig. 2.6 a-d. In general, temperature decreases with increases in altitude and from east to west. Every decrease in altitude of 102 m increases air temperature by 1°C (Heathcote 1983, 32). Due to the large variation in altitude found in the hills both the highest and lowest temperatures are found there. The area around 'Ajlun is the coolest and Rās Munief has an annual average temperature of 14.3°C whereas Ṭaiyiba, at an altitude of 373m, is the warmest with an average of 19.3°C (Jordan Climatological Data Handbook 1988, 14). More water stress is, therefore, experienced in the lower altitudes around Ṭaiyiba.

Summer is the most stable season in the Mediterranean region and has comparatively little variation in temperature from year to year (Shehadeh 1985, 29). August daytime temperatures at Irbid and Ramtha, on the plains, reach an average maximum of 31-32°C. In the hills, Ṭaiyiba reaches an average August daytime temperature of 33.2°C and Rās Munief is the coolest at 26.5°C (Jordan Climatological Data Handbook 1988, 15).

Although winter temperatures are comparatively mild, ground frosts do occur, especially in January. The highest altitudes of the hills are the most susceptible to frost. On average, Ras Munief experienced 29.3 days of frost per year (1976-87) whereas Irbid and Ramtha recorded 19.3 (1963-87) and 18.5 (1976-81) days respectively (Jordan Climatological Data Handbook 1988, 25). Winter temperatures are important as they affect the germination success of cereal and legume crops. Frost can have a particularly detrimental effect on, for example, the developing legume plant in the flowering stage (Harris 1990, 29). The severe winter of 1991-92 resulted in a very poor legume harvest.

2.2.3 Climate - Summary

Most of the differences in climate experienced on the plains occur from west to east. Generally, the western plains are comparatively wetter but the climate becomes hotter and drier towards the east and south. Ramtha is the most eastern location where wheat is regularly cultivated. Most of the variation in climate in the hills is caused by differences in altitude. Around 'Ajlun the climate is comparatively cooler and damper but as altitude decreases (especially to the north and west), temperature increases and the climate becomes more arid. In the hills, the nature of the landscape means that a comparatively high degree of climatic variation exists (i.e. microclimates are common); for example, a slightly different climate exists in a valley than does on an exposed north-facing slope.

2.3 Geology and Soils

2.3.1 Geology

The study area is within the 'North-east Jordanian Limestone Plateau' (Bender 1974, 21). The main geological units of the study area are shown in Fig. 2.7. Within the study area, there are, basically, two limestone series: the "Ajlun Series'; and the 'Balqa Series' (Bender 1974, 73; Burdon 1959, 37-43; Quennell 1951, 99-102). Both series have deposits formed in the Upper Cretaceous but the Balqa Series is younger. In the Yarmouk area, there are also some Balqa chert-limestone and chalky-limestone deposits belonging to the Tertiary period (Bender 1974, 83). The 'Ajlun Series, as the name would suggest, commands the landscape around 'Ajlun whilst the Balqa Series is dominant in the north of the study area (both series, incidentally, have a wide distribution in Jordan). Only the Balqa Series is found on the plains (cf. Fig 2.2a), but both series are found in the hills - limestones from the Balqa Series are found in the north and west of the hills zone. The 'Ajlun Series, however, is dominant in the hills zone (cf. Fig. 2.2b). The Balqa Series limestones tend to contain chalky levels whereas 'Ajlun Series limestones contain dolomitic rock.

There are two other significant geological units within the study area. First, overlying the Balqa Series in the north are some basalt deposits that represent Miocene to (geologically) 'recent' volcanic flows (cf. the 'basalt plateau' (Howard & Mitchell 1978, 86-87)). Secondly, widely distributed across the northern extent of the study area are quaternary deposits (see 2.7). Due to the deeply dissected nature of the study area, different levels and manifestations of the geological sequence can be dramatically exposed in the course of the area's major wadis.

2.3.2 Soils

There are two main soil taxonomic units: xerochrepts and chromoxerts (USDA Soil Taxonomy) present in the study area. Both units have been developed under xeric moisture regimes and are, generally, very productive soils. Broadly speaking, the xerochrepts are found in the hills and the chromoxerts on the plains.

2.3.2.1 Xerochrepts - Shallow Red Mediterranean Soils and Lithosols

These are common in both the hills and plains zones, but are more typical of the former. Xerochrepts broadly correspond to cambisols (soils weathered 'in situ') in the FAO-UNESCO taxonomy (1974). They are broadly distinguished by their ochric (low organic content) A horizon, cambic B horizon and calcic (high calcium carbonate content) subsurface horizon. There are different sub-units which are distinguished by different hard geology and profile development. Moorman, in an early survey of the area, classifies these soils as shallow red Mediterranean soils and lithosols (shallow mountain soils) (Moorman 1959, 34-36). The surface of these soils can be quite stony.

2.3.2.2 Chromoxerts - Deep Red Mediterranean Soils

These are the vertisols (FAO-UNESCO taxonomy) that are characteristic of much of the plains land near Irbid. They can, however, also be found in the hills zone situated in valley bottoms. They have a characteristic dark brown to reddish colouring and are deep, clayey soils (with high amounts of montmorillonite). Moorman classifies these soils as deep red Mediterranean soils (Moorman 1959, 33-4). Vertisols have a high potential for agriculture and have a high water-holding capacity (FitzPatrick 1986, 174). The deep cracks that develop in these soils over the winter months can, however, cause damage to tree root systems (Qudah & Jaradat 1988, 84). The high clay content can make cultivation difficult as they become unworkable immediately following rain.

2.3.2.3 Local Soil Classification

Locally farmers divide cultivable soils into 'red', 'white' and 'black' categories. Red soils are considered to be the best for arable crops (and particularly wheat) and are found both in the hills and on the plains. The red soils appear to include both xerochrepts and chromoxerts (i.e. the local terminology is similar to Moorman's broad grouping of red Mediterranean soils). White and black soils are thinner and generally considered to be less productive (and also unsuitable for wheat).

2.4 Vegetation

As with the climate, the vegetation of the study area has a principally Mediterranean character, although there is some limited encroachment into the so-called Irano-

Turanian region. The Eastern Mediterranean flora has been divided into two climatogenic vegetation zones and the north-western corner of Jordan falls in the Eu-Mediterranean belt (the Oro-Mediterranean belt is located in areas attaining higher altitudes). Phytosociologically, the vegetation constitutes one of the commonest classes of the East Mediterranean - the Quercetea calliprini (Kermes-oak shrub vegetations) and consists of thermophilous, mainly evergreen forests, maquis and dwarf-shrub vegetation (M. Zohary 1973, 501). The forest and maquis communities represent the most species rich environments in Jordan and include large numbers of ruderal and segetal species. This kind of open oak forest is, incidentally, exactly the environment where the wild progenitor species of the Near Eastern Neolithic founder crops are currently located (D. Zohary 1989, 367).

The following discussion describes the plant communities of the study area and defines vegetation zones according to those communities as well as in reference to the level of degradation of the forest or shrub. These vegetation zones are important co-variables which will be used in the canonical vegetation analysis of cereal fields (chapters 4 and 7). The division of the zones relies heavily on the work of Feinbrun and Zohary (1955), Long (1957), al-Eisawi (1985), and M. Zohary (1973), but also refers to personal observations. It should be stressed that the phytosociological communities detailed here, as part of the vegetation zones, are not absolutely discrete and that there is some overlap between, in particular, the sub-shrub and herbaceous components of communities defined by their tree or shrub strata. Furthermore, the communities which are usually interpreted as representing greater degrees of degradation can appear in more than one of the vegetation zones. This apparently confusing situation is analogous to plant communities in Greece where Rackham suggests that the Mediterranean flora should be envisaged as a mosaic rather than a series of (less and less degraded) stages eventually reaching a climax (forest) community (Rackham 1982, 188). In this way, the plant communities can be more easily viewed as representing factors such as geology, soil type, and microclimate, as well as human influence.

The distribution of the vegetation groups is shown in Fig. 2.8. There are four hills vegetation groups: 'evergreen forest', 'degraded evergreen forest', 'degraded deciduous forest' and 'degraded mixed forest' (this last group is not discussed below as a separate category). There is just one plains vegetation group which is under the category of 'plains vegetation'. In addition to the general zones, the segetal associations of the southern Levant which are potentially applicable to the study area are also discussed.

2.4.1 Evergreen Forest

Surrounding 'Ajlun and in the vicinity of Jarash, in the sub-humid bioclimatic zone and the higher altitudes of the semi-arid zone, are situated dense stretches of pine forest and oak maquis. The pine (*Pinus halepensis* Mill.) forest occurs in high altitudes, generally above the 700m contour, and can stand up to 10 metres in height (al-Eisawi 1985, 51). This forest falls into the alliance Pinion halepensis orientale (within the class Quercetea calliprini) and corresponds to the association of Pinus halepensis-Hypericum serpyllifolium (Eig 1946, 191; Long 1957, 19; M. Zohary 1973, 524). Its undergrowth has maquis components and indeed, in some places, the shrubs under the pine trees have grown so dense that the pines have been unable to regenerate and have been replaced by oak maquis.

The area to the north of 'Ajlun is dominated by evergreen oak woodland (Plate 1) and is part of the Quercion calliprini alliance and, specifically, the association Quercus calliprinos-Pistacia palaestina (Eig 1938; Eig 1946,191; 17; Feinbrun and Zohary 1955, 17; Long 1957, 25; M. Zohary 1960; M. Zohary 1973, 511). This type of vegetation is referred to as 'maquis' and denotes Mediterranean woodland dominated by sclerophyllous evergreen low trees and shrubs up to a height of c. 4 m (M. Zohary 1962, 83). Although called evergreen, major components of this association are deciduous such as *Pistacia palaestina* Boiss. and *Crategus azarolus* L.. The soil types upon which this association grows are also comparatively well aerated and nitrate rich, even if somewhat thin in areas, and a number of authors have commented on their suitability for agriculture (e.g. Long 1957, 26; M. Zohary 1960, 71). Rabinovich-Vin working in the Upper Galilee found that *Q. calliprinos* Webb (syn. *Q. coccifera* L. var. *calliprinos* (Webb) Boiss.) is dominant on dolomitic rocks (also found in 'Aljun Series limestones) and deduced that the abundance of magnesium is a key factor (Rabinovich-Vin 1983, 84).

2.4.2 Degraded Evergreen Forest

Surrounding the oak and pine woodlands lie patches of garrigue and batha Mediterranean vegetation. 'Garrigue' is a French term for sclerophyllous shrub standing up to 1 m in height. The term 'batha' is a Biblical word first used by Eig to denote Mediterranean dwarf shrub vegetation not exceeding a height of 50 cm and consisting of dwarf shrubs and perennial herbs (M. Zohary 1962, 111). The plant communities falling into this group are usually interpreted as heavily degraded forest (Eig 1933, 185). Studies in the southern Levant, chiefly based on observations of re-vegetation on abandoned agricultural terraces and areas protected from grazing, have resulted in some researchers identifying a succession sequence that progresses from annual to perennial weeds, garrigue to batha and finally, from maquis to forest (for example, M. Zohary 1962, 98-99; Nahal 1981, 83).

In northern Jordan, garrigue takes a slightly different form to equivalent communities in Palestine (Feinbrun and M. Zohary 1955, 20 and Long 1957, 27). The association, however, is still dominated by *Cistus creticus* L. (syn. *C. villosus* L.) and *C. salviifolius*

L. (Eig 1938, 6) and is located in clearings within and around the pine, mixed oak and pine, and evergreen oak woodlands (Long 1957, 27).

The most widespread batha community in the study area, and one of the most xeric types of Mediterranean batha, belongs to the order Ballotetalia undulatae (M. Zohary 1973, 541). There is an abundance of annuals within this order which includes western Irano-Turanian steppe taxa as well as exclusively Mediterranean species. According to Long, the association of Salvia dominica-Ballota undulata (Feinbrun and M. Zohary 1955, 20-21) covers more than 75 percent of the pastoral land in the semi-arid zone of northern Jordan (Irbid to Shaubak (c. 200 km south)). Long also considers that this group is a sub-association within the association characterised by *Ononis natrix* L. var. *stenophylla* Boiss. and *Anchusa strigosa* Banks & Sol. (Long 1957, 42 and first outlined by Eig 1946, 198). *Poa bulbosa* L. is very common in this association along with so-called 'forest relict species' such as *Rhamnus palaestinus* Boiss., *Asparagus aphyllus* L. and *Sarcopoterium spinosum* (L.) Sp. (syn. *Poterium spinosum* L.) (Long 1957, 43).

2.4.3 Deciduous Degraded Forests

There are two associations of deciduous broad-leaved oak woodlands within the study area. Only one, the association Quercus ithaburensis-Styrax officinalis (within the alliance Quercion ithaburensis) (Eig 1933; Long 1957, 31; M. Zohary 1973, 520), is included in this group. It is situated in the north-west of the study area and surrounds the Yarmouk river, Um Qeis and Deir Abū Saīd. This type of forest occurs at lower altitudes (typically between 300 m and 600 m) than *Q. calliprinos* (it is more tolerant of aridity), is associated with the warm semi-arid bioclimate and edaphically appears confined to Eocene rocks (Feinbrun and M. Zohary 1955, 19). Unlike the evergreen oak forest, the deciduous oak forest is not well protected and is, therefore, subject to extreme degradation (al-Eisawi 1985, 53).

Overlap can occur between the degraded evergreen forests and degraded decidous forests of the above association. Therefore, a 'degraded mixed forest' zone has been included as a separate category in the analysis (see Fig. 2.7 and chapter 7). Plate 2 shows cultivation in the mixed forest zone.

The second deciduous oak association (not included in this category) groups together *Q. ithaburensis* Decne. with *Pistacia atlantica* Desf.. Remnants of this woodland are located on the lower slopes of the Wadi Yarmouk and the eastern part of the Irbid plain as far as Ramtha (Long 1957, 33). It lies on the eastern fringes of the next group: plains vegetation.

2.4.4 Plains Vegetation

The deep soils (largely vertisols) which cover the fertile plains around Irbid are currently heavily cultivated. The virtually uninterrupted patchwork of agricultural plots (see Plate 3) means that it is difficult to speculate what perceived 'climax community' might actually have existed in this zone. The extent to which non-cultivation communities contribute to the weed flora of the fields appears to be limited. In the available literature, however, it is argued that, under the 'natural' course of events, a 'forest or maquis climax' is probable (Feinbrun & M. Zohary 1955, 20 and al-Eisawi 1985, 54) and this area is linked with deciduous forest associations (see 2.4.3 above).

2.4.5 Segetal Plant Communities

Perhaps the most important method by which forest, maquis and shrub communities are seen to have been lost throughout the Mediterranean region is by clearance for cultivation (Tomaselli 1977, 56). Once again, it is M. Zohary (1949-50) who has considered the segetal plant communities of the southern Levant in most detail. In total, Zohary estimated that segetal weeds make up a sizeable 20.3% (458 species) of the total flora for Western Palestine (M. Zohary 1949-50, 389). Although Zohary's research concentrates on 'Western Palestine' (contemporary Israel and the Occupied Territories), some of his divisions appear to be applicable to the study area. Additionally, Zohary's observations have particular interest as they were made at a time largely prior to the adoption of modern mechanised farming techniques.

The weed plant communities of the Middle East are included in the class Secalinietea orientalia by M. Zohary (1973, 365). The order Triticetalia orientalia comprises all the segetals occurring in non-irrigated winter and summer crops within the East Mediterranean territory and its adjacent Irano-Turanian or Euro-Siberian borderland (M. Zohary 1973, 636). For dry-farming areas in 'Western Palestine', Zohary distinguished four alliances of segetal associations - two of which are potentially applicable to north-western Jordan. He noted no perceivable differences between the segetal communities of different cereal crops (wheat, barley, oat, and rye) (M. Zohary 1949-50, 389). He did, however, note some differences between summer and winter sown crops but did not define these differences.

The first alliance with potential application to the study area is Prosopidion farcatae segetale which is distributed on the heavy alluvial and colluvial soils of the coastal plain, the upper Jordan Valley and intermountain valleys mainly within the Mediterranean territory (M. Zohary 1949-50, 393). It has one association: the Scolymeto-Prosopidetum factae (Prosopidetum farcta, Eig 1946) (M. Zohary 1949-50, 394; M. Zohary 1973, 636).

The second alliance, Ononideto-Carthamion tenuidis is confined to the terraces and plateaux of the Mediterranean hills and mountains (M. Zohary 1949-50, 393). Whilst Zohary comments that this alliance is fairly homogeneous he also states that, on the edges as well as within the cultivated plots, it can contain components of the non-agricultural plant communities with which the alliance's distribution overlaps, in particular, Quercus calliprinos-Pistacia palaestina, Q. ithaburensis-Styrax officinalis and Pinus halepensis-Hypericum serpyllifolium (M. Zohary 1949-50, 407). The association defined by Zohary, based on Eig (1946), is Ononis leiosperma-Carthamus tenuis (M. Zohary 1949-50, 397; M. Zohary 1973, 638) (*Ononis leiosperma* Boiss. is the former name used by Zohary for *O. antiquorum* L. var. *leiosperma* (Boiss.) Post).

From preliminary observation of weeds in the study area, it appeared that these two alliances/associations broadly correlated with weed floras found on the plains (Scolymeto-Prosopidetum farcatae) and hills (Ononis leiosperma-Carthamus tenuis) zones. The validity of this observation will be assessed in chapter 7. A diagram of the phytosociological hierarchy is presented below in Fig. 2.9.

2.5 Local History

The study area has for most of the last 400 years existed in part of the socially fluctuating margin between sedentary and nomadic modes of existence. For a large part of this period the farming population (the fellaheen) was generally submissive to the dominant nomadic tribes (the bedouin), although the two groups should not be viewed as entirely distinct (i.e. there existed a 'continuum' in modes of existence between farming and pastoralism). Today, however, lifestyles have altered dramatically and a minority of the population work directly on the land - either as farmers or pastoralists. Most of the population is now 'settled'.

2.5.1 The Ottoman Period

The study area lies within the south-eastern section of Ottoman Syria and almost exactly corresponds to the former district of 'Ajlun. Ottoman rule began after the demise of the Mamluks in the early sixteenth century. There are tax records documenting significant agricultural productivity for parts of south-eastern Syria for this period. Records for the district of 'Ajlun reveal a high level of tax collection and furthermore, the district appears to have been the most economically important area east of the Jordan (Hütteroth and Abdulfattah 1977, 85). After the end of the sixteenth century, however, Ottoman authority and influence declined and for two hundred and fifty years, a period spanning through to the mid-nineteenth century, the region lay largely outside the Ottoman order (Rogan 1991, 8).

During the long period of waning Ottoman authority, the extent of cultivation, the so-called 'desert line', appears to have receded across all Syria, but districts near the eastern and southern margins of cultivation seem to have suffered the most (Lewis 1987, 13). The reasons for the abandonment of settlement and associated depopulation are complex, but the two critical factors appear to have been the environmental vulnerability of these areas to drought combined with the fact that they were the most exposed to bedouin attack. Early travellers as well as more recent scholars have observed that the absence of authority strengthened bedouin hold over large parts of the region or, at least, encouraged a nomadic mode of existence (Hamarneh 1985, 46). The mountainous area around 'Ajlun, however, seems to have acted as a region of refuge due, in part, to its defendable hilly terrain and agricultural fertility. Lewis calculated that eighty villages remained inhabited by comparing the villages noted as being occupied in the early nineteenth century travellers' accounts (Burckhardt 1822; Robinson & Smith 1856; Seetzen 1854-9) to those known from the late sixteenth century (Lewis 1987, 21). Settlement declined as the hills descended to the east and, for example, Jarash was only permanently re-inhabited in the late nineteenth century with the arrival of the Circassian community (Lewis 1987, 109).

In 1851, during the Ottoman Tanzimat, 'Ajlun was the first south-eastern district to be re-incorporated into the administrative apparatus of the Ottoman province of Syria (Fischbach 1990, 26; Rogan 1991, 11). Following this, the extent of the settled population increased. During the 1880's, Cuinet estimated the population of the district of 'Ajlun as 30,000 (Cuinet 1896, 487). Schumacher estimated the population of the northern part of 'Ajlun as 10,460 for 39 villages; an average of 48 people per square mile (18.5 people per km^2) (Schumacher 1890, 26). By 1914, almost at the end of the Ottoman period, the population was calculated to be 61,967 (Karpat 1985 in Rogan 1991, 201). The reassertion of Ottoman authority promoted the expansion of the agricultural mode of existence and worked to the detriment of the region's powerful nomadic groups who had previously extracted a heavy 'tax' (the khuwa) from allianced village communities in return for protection (Rogan 1991, 14). The Ottoman land reforms of the nineteenth century also helped to change the pattern of land use in favour of the agriculturalists and agricultural production therefore increased (Amadouny 1993, 76).

The Hauran (of which 'Ajlun was a part) was Ottoman Syria's 'granary' (Issawi 1988, 214). The district of 'Ajlun appears to have been the most productive wheat district in 1901 (see Table 2.1). Cuinet reports that relative wheat returns for the Hauran districts were 10 to 1 in 'Ajlun (but cf. Table 2.1), 15 to 1 in Jebel Druze and 20 to 1 on the Hauran plain around Der'a (Cuinet 1896, 345). The accurateness of the very high returns has been questioned recently (cf. Tabak 1991, 143), but the main point remains - yields were comparatively good. 'Ajlun also exported its surplus grain (unfortunately, the quantities are unknown) to Damascus and at the very end of the Ottoman period, after the opening of the Haifa branch line of the Hijaz railway in 1907, to the Palestine coast and presumably, Europe (Rogan 1991, 254).

The late Ottoman period was also significant as a period of land reform. This will be discussed further under the section on land tenure (section 2.6).

2.5.2 Transjordan

Following the First World War and the defeat of the Ottoman army in 1918, the Allied powers divided the Middle East into 'spheres of influence' according to the Sykes-Picot agreement of 1916. In 1921, Adbullah, second son of Sharif Hussein of Mecca, became Emir of the recently British mandated territory of Transjordan (Lewis 1987, 200). The British authorities and Emir Abdullah then proceeded to create a separate administration and state apparatus (i.e. separate from Syria and Palestine) for the emerging country of which the study area formed the furthest north-western part.

The newly mandated administration viewed agriculture as the most important part of Transjordan's economy and hoped that it would make the new territory self-supporting. They identified land reform as key to changing what were considered inefficient and unproductive methods of farming and the changes they implemented will be discussed below (see 2.6). Apart from land reform, there was no real agricultural policy formation until the early 1930's and this shift was primarily prompted by the onset of a cycle of poor rainfall years which lasted from 1924 to 1936. In the event, the other initiatives that were implemented, such as seed propagation schemes, water bores and the limited import of mechanised agricultural machinery, had a fairly restricted impact on the region's farming patterns and also failed to make Transjordan self-supporting (Amadouny 1993, 86-127). This type of record has lead Hamarneh to propose that the British administration operated a 'stand-still' policy for Transjordan (Hamarneh 1985, 210).

Despite this slightly gloomy assessment, Konikoff provides some more encouraging figures for agricultural activity in the study area during the Mandate. Excluding the drought years, there was generally a rise in cereal production between 1927 and 1939 and cereals continued to be exported, despite the 'poverty' of Transjordan, in increasing quantities to Palestine (Konikoff 1943, 47). During the 1930's, the area around 'Ajlun was the centre of unirrigated vegetable growing (chiefly okra, tomatoes and cucumbers) and it possessed, along with es-Salt, the best vineyards in the country (Konikoff 1943, 48). Table 2.2 lists the main grain crops grown in the study area and the area of (in percentages) each crop covered for 1933. Wheat was clearly the most important grain crop, however, in two out of three of the areas surveyed legume crops covered a greater area than barley - the second most important cereal.

Amadouny points to one interesting initiative, in terms of crop management practices, that was promoted in northern Transjordan. In an attempt to reduce soil erosion officials from the Department of Agriculture visited villages 'lecturing of the merits of a three-year rotation pattern' and, in addition,' school teachers were instructed in the merits of crop rotation in order to introduce the practice onto the plots in school gardens that were used for demonstrating modern methods of cultivation' (Amadouny 1993, 115). By 1935, 39 villages in the north were reported to have changed from a two to a three year rotation regime.

The most significant and ambitious policy of the Mandate was the campaign which registered the lands of Transjordan in the name of its newly recognised owner(s) (with some exceptions). For agricultural lands, this meant the break-up of mushā'a: the long-established system of communal land-holding. Mushā'a was still widespread in the study region and, for example, prior to 1933, when operations began, 96% of the villages in the Irbid district were mushā'a (Fischbach 1990, 27). The repercussions of this measure for future agricultural land use extended far beyond the end of the Mandate period.

2.5.3 The Hashemite Kingdom of Jordan

In 1946 Abdullah was enthroned as king of the independent Hashemite Kingdom of Jordan. Since then, the Kingdom has faced considerable social, economic and political difficulties. Following the pronouncement of the state of Israel what was to become the occupied West Bank (including 750,000 people) was annexed to Jordan - thus making the majority of people in Jordan Palestinian (including a high proportion of refugees). In 1951, King Abdullah was assassinated and from 1953 onwards, King Hussein has held control - maintaining the Kingdom through some very difficult periods. In 1967, the West Bank was taken by Israel and a civil war ensued within Jordan. Northern Jordan saw much of the fighting and 'Ajlun was the last area from which the guerrillas were removed. After 1974, the political situation eased and subsequently, Jordan has seen considerable social and economic improvement. The country, however, remains dependent on foreign aid and vulnerable to external pressures.

Since the late 1950's, government agricultural policy has largely centred on the development of irrigation in the Jordan Valley. The first stage of the East Ghor Canal - carrying water from the Yarmouk river - was completed in 1963. By 1980, the Valley accounted for over 90% of Jordan's agricultural exports (Seccombe 1985, xl). Subsequently, however, the importance of the Valley's produce for the export trade has declined. Attention has been paid to the dryland agricultural sector from the 1950's onwards (e.g. improving the production of cereal varieties and testing fertilisers) and more intensive efforts have been undertaken since the 1970's (el-Hurani 1989, 48-49) - especially following the establishment of local universities and institutions such as ICARDA. In general, however, agronomists have been disappointed by the take-up of modern methods by local farmers. The main initiatives and reasons for their slow uptake will be discussed further in chapters 3 and 6.

The population of the study area has grown enormously during this century. In 1992, the population of the Irbid governorate (slightly larger than the study area) was estimated at 979,000 with the population of Irbid set at 385,000 (Hunter 1994, 830). Part of this massive population rise is due to the influx of refugees from Palestine in 1948, 1967 and, most recently, from Kuwait following the war with Iraq (1990-91). Jordan also has one of the world's highest birth-rates. The current estimated population of Jordan is more than 18 times greater than it was in 1922 when Transjordan was formed - a rise from approximately 220,000 to 4,000,000 people.

2.6 Land Tenure

One of the main features of former agricultural organisation in the study area was that agricultural land was held communally under the system of mushā'a. Firestone refers to mushā'a as 'the most important system of land tenure in the nineteenth century Levant' (Firestone 1981, 813). Both the Ottomans and the British implemented land reforms which affected communal farming, but is was the British who finally privatised the ownership of agricultural lands.

2.6.1 Ottoman Land Reforms

The Ottoman Land Code of 1858 primarily aimed to regularise and modernise land-holding within the Empire and increase tax revenues. The reforms have been seen as an attempt by the state to privatise land rights, break down the system of communal land-holding and undermine the power and influence of tax-farmers and fief holders (cf. Firestone 1981, 826). Such dramatic social aims, however, are now considered as beyond the scope of the basically conservative Land Code (Gerber 1987, 71; Rogan 1991, 303). Instead, it is viewed simply as regularising reform, embodying many already existing developments (Mundy 1992, 218) and agrarian laws (Gerber 1987, 71). There was also, as mentioned above, the important fact that the Codes would provide more tax receipts. The aim of the Ottoman authorities to raise more tax revenues has been forcibly argued by Sluggett and Farouk-Sluggett (1984). In terms of dissolving communal ownership, new interpretations of the Land Code suggest that the new legislation 'neither contradicted co-ownership nor required its dissolution' (Firestone 1990, 106).

As part of the reforms, an obligation was imposed on all land-holders to register their lands in the government land registers and, in return, they would receive a title deed attesting to their rights (Gerber 1987, 72). 'Ajlun, in fact, was the only district to be systematically registered in what was to become Transjordan (Rogan 1991, 307). Agricultural lands were given priority during registration - a fact which has been interpreted as suggesting that, to the Ottoman authorities, 'the village was perceived primarily in terms of its agricultural productivity' (Mundy 1992, 221).

The Ottomans registered shares in agricultural lands rather than ownership of particular land units. This allowed many of the important features of mushā'a to continue.

2.6.2 Communal Farming (Mushā'a)- *in practice*

One of the key components of mushā'a was that plots of land were reallocated, on an 'egalitarian' basis, between farmers at regular intervals (apparently on an annual, biannual or up to 5 year basis). It has been called egalitarian because each group and cultivator in the village shared in all classes of land, from rocky ground to flat, fertile plains (Fischbach 1990, 27). Mushā'a, however, was not always in practice strictly egalitarian principally because when shares were allocated tribal strengths meant that certain tribes were more highly favoured than others (Fischbach 1990, 28). Even in cases where land was equally divided between tribes the 'division of land was not egalitarian because some clans had a higher number of nuclear families than others' (Hamarneh 1985, 82).

Bergheim describes the way in which village lands were divided for cases known to him in Palestine:

> 'supposing there are 20 *feddan* of land ... this land is first divided into four divisions (northern, southern, western and eastern) ... Each of these divisions is then again divided into 20 equal portions and this time by measurement; a line or rope is sometimes used, and not infrequently a long reed or ox goad, which measures generally about nine feet.'
>
> Bergheim 1894, 193

He also describes how the names of the fields, or parts of fields, were then written by the village scribe on stones which were then put into four bags, one bag for each division of the village. Small boys then drew out the names and fields were distributed between the shareholders (Bergheim 1894, 194). The over-riding principle is that land of varying qualities is divided equally between farmers without bias (see also Weulersse 1946, 99). Neil also notes that, under this system of allotment, one man may end up cultivating 20 or 30 separate strips of land (Neil 1890, 161). Additionally, 'due to the scrupulous application of the principle of equality', (Patai 1949, 439) parcels of land tended to be long and narrow so that in one village plots were recorded as being 2,300 yards long but only 5 yards wide (Waschitz 1947, 47 quoted in Patai 1949, 439 and Latron 1936, 193).

Individual cultivators did not have the exclusive right to choose what to cultivate on each strip of land. Rather, the decision of what to grow where was taken by agreement. Neil states 'a man may not sow any crop which he pleases on his strip or strips, but is compelled to grow the same produce as the rest of his fellow-farmers are growing in the field or district where his allotments lie' (Neil 1890, 160). Thus, for example, an area would be given over to wheat and barley, and others to legume crops and summer vegetables. As cereal crops were grown together a large continuous area of land would be released for grazing after the harvest was complete. These consolidated plots also limited damage by grazing whilst the crop was developing.

Villagers are reported to have paid heavy taxes to the Ottoman tax collectors. After 10 years of observation on the Sharon Plain in Palestine, Bergheim estimated that the tithe (tenth) rarely, if ever, averaged under one third of the whole crop (Bergheim1894, 198). Additionally, the villagers would provide hospitality for officials whilst taxes were being assessed (Bergheim 1894, 197) and, where tax payments were considered inadequate, troop detachments could be placed on villages in reprisal (Firestone 1981, 827). Firestone (1981, 826 referring to Wilson 1906, 291-2) argues that, while positions varied, the village as a whole was responsible for the payment of the tithe and that individual responsibility for paying taxes was one of the main changes resulting from the Ottoman Land Code of 1858. Thus Neil reported that 'each farmer then pays the proportion of the land tax due on the strips of land allotted to him' (Neil 1890, 159). The heavy fiscal burden placed on the farming population is stressed by Firestone who argues that 'land equalisation' was a collective response to oppressive tax burdens (Firestone 1981, 828). This and other explanations for the phenomenon of mushā'a are summarised below.

2.6.3 Communal Farming (Mushā'a)- *in theory*

A number of explanations have been given for the development and continuation of communal farming. Theories centre on the ability (or necessity) of groups to work together in situations of adversity, the prevailing system of tribal organisation and the vulnerability of 'sedentary' farmers.

The unreliable nature of the local climate has recently been stressed as an explanation. In this case, mushā'a is viewed as a kind of 'buffering strategy' such that during poor years scarce resources would be distributed equitably across a community (V. Amadouny and T. et-Tell pers. comm.). It has, in addition, often been commented that mushā'a was also practised on comparatively poorer arable land (e.g. Antoun 1972, 21).

Mushā'a can also be viewed as a kind of social 'levelling' mechanism between farmers and groups. The strict redistribution of land of different qualities meant that no-one person or group could accumulate wealth (although it is apparent that some groups had more shares in arable land than others). In this way, members of the community or group remained 'equal' or, at least, maintained their position. In emphasising the roles of the environment and the social organisation of the community, these two explanations stress the internal 'strength', or even 'rational nature', of local farming communities.

As noted above, Firestone has proposed (using parallels with nineteenth century Russia) that land equalisation was a collective response to oppressive tax burdens (Firestone 1981; 1990). He also, however, points to the system as one extending from vulnerability 'equalising villages ... seem to be largely amorphous, populated by weak clans or by splinter groups of bedouin in transition to sedentary life and individual families of cultivators ejected by political or economic circumstances from the production systems of their home tribe or villages - the lower more defenceless, more easily exploited strata of peasant society' (Firestone 1981, 830). In this explanation, therefore, the emphasis is placed upon the 'weakness' of farmers who practised mushā'a in the prevailing social hierarchy of the region. This theme has also been stressed by a number of earlier authors (e.g. Weuleresse 1946, 104).

At whatever point the 'real' strength lies, the dissolution of mushā'a had very important consequences for farming practices in the study area.

2.6.4 The Dissolution of Mushā'a in Transjordan

Whereas the Ottoman authorities had sought to regain overall possession of land, the better to release it for commercial purposes, the British opted for the complete privatisation of arable land (Amadouny 1993, 78). Early assessments of the farming conditions in Transjordan pinpointed mushā'a as a system which retarded agricultural development and kept the agricultural population poor - largely because it retarded investment (Patai 1949, 440-1). Land settlement involved the partitioning of mushā'a lands into individually held plots with permanent boundaries. Land registration conferred title primarily on local people. For the villagers in 'Ajlun, 92% of land was registered to local inhabitants (Fischbach 1990, 26).

By the 1930's, the equality of land division set out in the Ottoman era had been seriously eroded. Large population increases had caused tribes to subdivide their shares between developing tribal sections thereby creating smaller and smaller units. As land registration was based largely upon Ottoman shareholding, the 1930's land division reflected the inequalities that had developed. For example, in Malkā, the Fuqara' tribe was allotted 59% of the available land while the Fellaheen tribe only 11%

(with 30% not subject to tribal partition) (Fischbach 1990, 28). At the date of settlement (1933-40), there were over 34,000 landowners in the whole province, averaging 57 dunums each. By 1949, with increasing population and the local custom of divided inheritance, the number of landowners had increased to 42,000, each owning an average of 49 dunums (Fischbach 1990, 27).

Land settlement brought a profound change in the relationship between farmers and their land. They held a consolidated plot, or plots, with fixed boundaries and the ability to cultivate what they desired as, for example, an individual or nuclear family. Agricultural decision-making was transferred, therefore, from broader alliances (tribally or village based) to smaller, more independent units.

2.7 Kinship Ties

In northern Jordan local villagers are very much aware of bonds of kinship. People are keen to point out their association with a particular group, especially if it is considered to be one of the more prestigious ties and also frequently describe relationships between various members in some detail. Many villages are specifically associated with particular groups. For example, the village of Saum with the Shannag, Deir Abū Saīd with the Shraideh, and seven villages in the far north of the study area with the Obiedat. During the national elections in November 1990, notable groups were keen to have a member elected to Parliament.

Although kin ties are important, there is some confusion in the local usage of terms for different levels of affiliation. The histories traced for different groups are also not always consistent (cf. Antoun 1972, 46). This probably serves to emphasise, first, the differences between principally agricultural and principally nomadic groups whose kinship ties seem to be better defined and secondly, that kinship should perhaps be viewed also as an ideology, support network and way to resolve conflict rather than simply a description of socio-political organisation (cf. Abu-Lughod 1989, 280-84). In this way, kinship ties are more flexible and the groups do not always have to obey the perceived blood-line 'rules'. They are units upon which people can draw for support or, indeed, units from which people can break away.

The main social unit referred to by villages is the ā'ila. Classically, this is a patrilineal descent group whose blood relations can be traced back five generations (Taminian 1990, 19). The ā'ila was an important unit under the system of mushā'a - strips of land were divided between ā'ila who then divided the land among themselves on a smaller, usually, household (dār) basis. The ā'ilas link together to form the 'ashīra, a word normally translated as 'tribe'.

Kinship was very important for agriculture because, as noted above, households were organised into larger groups under the old system of land tenure and many agricultural operations were undertaken together, e.g. the cereal harvest. It meant a large pool of labour was available at times of agricultural stress. Since the break-up of communal land tenure, kinship ties have become less strong and the 'economic unit' is closer to the household (the residential unit and unit of consumption). These smaller units can and do, however, call upon broader bonds at particular times.

2.8 Summary

2.8.1 *Environmental Setting*

The study area has a typically Mediterranean climate which ranges from sub-humid in the high altitudes near 'Ajlun to slightly arid close to Ramtha. Most of the differences in climate experienced on the plains occur from west to east. Generally, the western plains are comparatively wetter, but the climate becomes hotter and drier towards the east and south. Ramtha is the most eastern location where wheat is regularly cultivated. Most of the variation in climate in the hills is caused by differences in altitude. Around 'Ajlun the climate is comparatively cooler and damper, but as altitude decreases (especially to the north and west) the temperature increases and the climate becomes more arid. In the hills, the nature of the landscape means that microclimates are common; for example, a slightly different climate exists in a valley than on an exposed north-facing slope.

Typically, plains soils consist of deep, clayey red soils (vertisols). Hills soils tend to be shallower (cf. cambisols), although they are also usually 'red' and have a high clay content. The plains soils are underlain by limestones from the Balqa Series. Limestones from the Balqa Series also underlie soils in the north of the hills zone, but to the south, limestones from the 'Ajlun Series are dominant.

The vegetation found in the study area is also typically Mediterranean although there is also a slight intrusion into the more arid Irano-Turanian zone. In this study, vegetation has been divided into five groups according forest type and degree of degradation. There are four groups in the hills: 'evergreen forest', 'degraded evergreen forest', 'degraded deciduous forest' and 'degraded mixed forest'. There is just one plains vegetation group which is categorised as the 'plains vegetation zone' (with 'continuous cultivation'). There appear to be two main segetal groups in the study area; one in the hills and the other in the plains. The more rugged terrain of the mountains and certain areas' unsuitability, without significant investment in clearance and terracing, for growing crops means aspects of the forest, maquis, garrigue and dwarf-shrub communities of the hills intrude into the segetal community found in the hills (cf. M. Zohary 1949-50, 406).

2.8.2 Social Setting

During the last century, there have been profound social and political changes in the study area. Since the re-establishment of Ottoman authority at the end of the nineteenth century, the settled population has dramatically increased. Today, the estimated population of the Irbid governorate (slightly larger than the study area) is close to 1 million people whereas in 1896, the estimated population of the Ottoman district of 'Ajlun was just 30,000. The political base of the area has also shifted from 'Ajlun to Irbid - from the hills to the plains. The study area was an important grain producing region for late Ottoman Syria and contains some of the best agricultural land to be found in the contemporary Hashemite Kingdom of Jordan.

Farmers have an entirely different relationship with their land to the one that existed one hundred years ago - instead of holding a share in communally held agricultural lands, farmers now own their plots of land outright. Land reforms were implemented by both the Ottomans and by the British during the mandate, but it was the latter who finally privatised land ownership on a western capitalist model. The change in land tenure and the commercialisation of the region have had profound implications for the prevailing social structure - shifting the operative emphasis from kin-networks to households.

During this century, the imposition of national borders has meant the area has been isolated from access to Palestine and the Mediterranean ports. Historically, however, the study area had perhaps the strongest trade links with Damascus and these links have also been curtailed to a large degree. The economic and political centre is now focused to the south of the study area at Amman.

Chapter 3 Crop Management Regimes

In a 'traditional' Mediterranean farming system, it is rare to find the same crop cultivated continuously on the same plot of land under non-irrigated conditions. Instead, crops are rotated. Moreover, crops are most frequently rotated in combination with a period when no crop is grown at all but the land is cultivated, i.e. a period of bare fallow. This is a critical feature of traditional Mediterranean farming and is the traditional management technique used to conserve soil moisture and restore soil fertility (Grigg 1974, 125; Semple 1932, 386). A two year rotation regime where bare fallow alternates with a cereal is one of the most common rotation regimes of the region.

The value of bare, or cultivated, fallow has recently been questioned by agronomists. Their research has shown that cereal-legume rotation regimes and continuous cereal cropping with the addition of fertilisers or manure are viable alternatives to bare fallow. This, therefore, begs the question why bare fallow has been such a pervasive and preferred practice for recent 'traditional' farmers - and is still an important crop management technique widely practised in contemporary Jordan - and whether it was always the 'norm' in antiquity (Halstead 1987, 82-83).

3.1 Cultivated Fallow

3.1.1 A 'Special Cultural Technique'

This study focuses on crop management practices in a semi-arid area where agricultural production is wholly dependent on precipitation. Agriculture in this area is termed 'dryland', in contrast to 'rainfed' because, first, moderate to severe water stress is experienced during a substantial proportion of the year, and secondly, special cultural techniques are required for sustained production (Harris 1991, 21). The principal 'special cultural technique' associated with Mediterranean cereal agriculture is bare, or cultivated, fallow (Grigg 1974, 125). It is the traditional management technique used to conserve soil moisture and restore soil fertility.

During a bare fallow year, no crop is sown and the land is left to 'rest' for a full summer, winter, and often, one more summer. In addition, the land is intensively tilled in preparation for the following winter crop (usually wheat). Earlier this century, Pinner described a year of cultivated fallow in Palestine:

'In the early part of the winter rain period the ground is ploughed once in a shallow manner by interspacing the plough-furrows; this sort of ploughing is called *sheqaq*. ... A second ploughing - *tani* - follows at the end of the heavy rains, at a depth of about 15cm with closely set ridges across the direction of *sheqaq* ploughing. ... A third and last ploughing is given after the late rains in the same way as the second but to a somewhat greater depth.'

Pinner 1930, 52

This description emphasises that bare fallowing is traditionally characterised by a large number of tillage operations; hence bare fallowing is also known as cultivated, or clean, fallow. Summer crops can also be grown during a fallow year (see 3.1.5). The number of operations may not just be limited to three but could be as high as six (Jaradat 1988a, 209), the final operations taking place after the end of the late rains. Increasing the number of tillage operations is traditionally thought to increase the amount of moisture conserved. In the village of Kufr el-Mā, within the study area, Antoun reports the proverb, 'He who has tilled his soil twice has watered it once' (Antoun 1972, 8). The ability of fallow to conserve moisture is more frequently quoted than its property to restore soil fertility (for example, Grigg 1974, 125; Papendick 1989, 260; Semple 1932, 386).

The term 'cultivated' fallow will be used to describe fallowing where there are repeated tillage episodes during the year (with or without the cultivation of summer crops). Bare fallow will be used specifically to refer to cultivated fallow without summer crops.

3.1.2 The Principles of Cultivated Fallowing

Tillage is critical to the success of cultivated fallow. There are three ways in which moisture is lost from soil: evaporation from the soil surface, transpiration by growing plants and percolation into deep soil layers beyond the reach of plants (Arnon 1972a, 420). For semi-arid areas, and particularly those with shallow soils, the third cause of loss is generally small (Forbes 1982, 204) and not likely to occur as long as precipitation is below 500 mm (Janssen 1972, 249). The most effective way to increase the amount of water held within a soil is to increase infiltration and minimise evaporation and transpiration (evapotranspiration). This can be achieved by tillage.

Enhanced infiltration is best achieved with tillage that maintains a clodded or ridged surface (Unger 1984, 39; Godwin 1990, 66). Burwell *et al.* (1966) evaluated the effects of porosity and surface roughness resulting from several tillage methods on the infiltration of simulated rainfall. They discovered that water intake was more closely related to surface roughness than to total pore space. Surfaces which had been smoothed resulted in more rapid soil dispersion and sealing, which reduced infiltration. A rough irregular surface, therefore, aids infiltration. A rough surface can also play a part in reducing wind and water erosion (Godwin 1990, 55). The pre-winter tillage episode of a cultivated fallow period, as outlined by Pinner above, corresponds to this recommendation. Additionally, the primary tillage operation eases further tillage in the spring (Jaradat 1988a, 212).

'Reduced evaporation can be achieved by deeper storage of water within the root zone and improving the micro-climate at the soil-air interface' (Unger 1984, 33). Experimental results have added support to the suggestion that when the soil surface has dried to a depth between 200 and 300 mm, the effect of capillary action, which draws water to the surface, will be reduced to some extent (Henderson 1979, 229). Tillage influences the water content of the tilled surface, as open soils lose water more readily than firm soil because of mass air movement in large voids. Although a tilled surface will rapidly dry out, spring tillage causes poor contact with the untilled moister levels underneath and, therefore, slows down the movement of soil water to the surface. In effect, a dry soil mulch is created which assists moisture retention in the root zone (Papendick 1989, 260). The deep cracking that splits open heavy soils during high summer temperatures, and through which moisture evaporates, is also avoided (Keen 1946, 51).

The second way in which soil loses moisture is through transpiration by plants - plant root systems penetrate far into the soil drawing up water from low levels. The mouldboard plough, developed in the temperate zone but widely used today in the Mediterranean region, is the most effective way to remove weeds as it inverts a strip of soil over on its back completely burying weeds. The mouldboard plough, however, is not ideally suited to the Mediterranean situation because it encourages erosion. Repeated tillage with a traditional ard, or scratch-plough, will dislodge and kill most annual weed species. Perennial weeds are difficult to destroy by ard tillage but they can be controlled by cutting, or grazing, at frequent intervals to deplete food reserves stored in roots or stems (Jordan & Shaner 1979, 275). In general, the earlier weeds are eliminated in their growth cycle, the less moisture will be lost from the root zone by transpiration (Papendick 1989, 263; Unger 1984, 85). Some farmers in Jordan, however, are known to allow limited weed growth on fallow land to supply valuable fodder for livestock (Jaradat 1988a, 210) and, although the weeds are cut, this practice decreases the effectiveness of fallow (also see section 3.1.6 describing 'weedy fallow').

In summary, therefore, cultivated fallow enables moisture to be stored in the root zone by opening the soil to infiltration over the winter months and reducing evapotranspiration in the summer. Figure 3.1 shows a schematical representation of the principles of fallow (in a wheat-bare fallow rotation regime).

Cultivated fallow is also said to increase soil fertility, particularly nitrogen content. This is because fallowing allows time for nutrients to be mineralised from organic matter and crop residues contained in the soil. Tillage also promotes rapid mineralisation. Loizides, working on cereal-fallow rotation in Cyprus during the 1940's, calculated that total ammonia and nitrate nitrogen content in the soil (primarily derived from nitrogen fixation) was five to six times greater after bare fallow than after wheat (Loizides 1948, 213). He also found that fallowing increased available phosphorous.

In Australia, a debate ran for a number of years as to which was the more important consequence of cultivated fallow - increased nitrogen or increased water. It was inevitably decided that there is a strong interaction between the two and that one or the other contributes more according to the rainfall regime (Harris *et al.* 1991, 240). Soil moisture seems critical at low levels of precipitation and increased fertility is more important at high levels of precipitation. Soil fertility is dependent upon soil moisture because minerals are fixed in the soil by micro-organisms which are dependent upon receiving oxygen in solution. Organic matter is not only a source of plant nutrients and, in combination with crop residues, an aid to nutrient recycling processes, but also improves soil structure which helps to improve soil-water relations (Godwin 1990, 39). There is the disadvantage, however, that the clean tillage practices which are such an important component of cultivated fallow, result in a general decline in soil organic content due to the burial and rapid decomposition of crop residues (Unger 1984, 120).

In recent years there has been a great deal of interest in reduced tillage or no-tillage systems (also called conservation tillage) which are primarily used to reduce erosion (Papendick *et al.* 1991, 67). They also have the additional advantage of requiring less labour to implement. A no-tillage system heavily depends upon the use of herbicides to remove weed cover, an option not available until this century. In the past, however, weeds could have been reduced by grazing, cutting or even by hand pulling.

In a dryland Mediterranean situation, however, the previous discussion suggests that soil-water would not be conserved effectively without tillage. First, without the absorptive quality of a loosened soil surface, the velocity of water collecting as run-off would be increased, a factor which could also potentially increase soil loss (Unger 1984, 113). Secondly, reducing the number of tillage operations during springtime would limit weed control and encourage evaporation. The number of spring tillage operations that could be eliminated without causing significant moisture loss is currently in debate. Preliminary experiments conducted at Ramtha in northern Jordan investigating reduced tillage systems have yielded inconclusive results (Jaradat 1988a, 217). On the whole, no-tillage and reduced tillage cropping systems have not yet been entirely successfully applied in the Mediterranean region (Bolton 1991, 39).

Running hand-in-hand with investigations into no tillage and reduced tillage systems has been research into plant matter mulches. Here, plant matter, usually crop residues, is either left on the soil surface, or loosely combined with up to the top 150 mm of the soil. This is in contrast to a clean tillage system where all plant residues are covered and tilled-in to greater depths (Unger 1984, 107). Mulches are advantageous because they absorb water, thereby inhibiting run-off and erosion, as well as reducing evaporation. They also provide valuable organic matter which can be mineralised to increase soil fertility. Mulching is now used in many areas of the USA. Research, however, has shown that this technique is not particularly effective for dryland farming systems where rainfall occurs in widely scattered events (FAO 1971, 10). This is because, during long dry periods, water held in the mulch is totally evaporated. Weed and pest problems can also be introduced requiring the application of chemicals. Furthermore, reduced tillage and residue mulch systems require equipment and, critically, sufficient crop residues to be successful.

3.1.3 Field Experiments

Field experiments investigating the amount of moisture stored under cultivated fallow have produced highly variable results. For example, Janssen calculated that in Turkey the contribution of moisture stored in the preceding bare fallow year to transpiration was between 45% and 65% thus showing fallow to be 'indispensible' (Janssen 1972, 258). Studies in the wheat-bare fallow areas of the Great Plains of the USA, by contrast, revealed that, over a range of practices, only 16-30% of precipitation was retained (Godwin 1990, 68). Even lower down the scale, results from ICARDA's station at Breda, northern Syria, showed that in trials over a six year period less than 10% of the seasonal precipitation was stored by the end of the following summer (Harris *et al.* 1991, 239). Similar low percentages have been noted from dryland areas in Australia (French 1963a).

In an experiment conducted at the village of Hawara in the study area, soil moisture levels after a bare fallow year (unfortunately, details of the tillage operations are not given) were found to contain 48 and 97 mm more water than the soils of areas planted with summer crops and wheat respectively (Saimeh and Battikhi 1985, 86). Saimeh and Battikhi estimate that after wheat has reached its flowering stage, each additional millimetre of rain is believed to produce a one kilogram increment of wheat per dunum (1000 m^2) provided that all other conditions are optimal, i.e. rainfall is good, soil is fertile and wheat varieties are high yielding (Saimeh & Battikhi 1985, 69). Although growing summer crops in a year of cultivated fallow uses some of the stored moisture, some water is still generally conserved.

Limited experimental evidence is available which assesses the effect of cultivated fallow on soil nutrients. One notable exception, however, is Loizides work in Cyprus (see

3.1.2). From these experiments, Loizides concluded that bare fallow is more important for its ability to restore soil fertility than for its moisture conserving properties (which were negligible in his experiments). Bare fallow can, therefore, be replaced by continuous cereal cultivation so long as sufficient manure and/or fertilisers are applied (Loizoides 1948, 216). It is worth noting, however, that Loizides measured soil water at a comparatively high level in the soil profile - between 12 and 24 inches (c. 300-600 mm) - and moisture is thought to be more effectively stored at deeper levels (Harris *et al.* 1991, 240). Loizides may, therefore, have undervalued the ability of bare fallow to conserve moisture, although it is clear from his work that the nutrient enriching capacity of bare fallow should not be underestimated.

There are some long term assessments of bare fallow from semi-arid zones in the USA. One study, initiated in 1931, provides an insight into the long term effects of practising a cereal-fallow rotation regime in an area that had not previously been used for cereal production. During the first 50 years of cultivation, large losses of organic matter occurred. Only the addition of 22.4 t/ha of manure and straw residue to the soil prevented a decline in soil nitrogen and carbon (Ramussen *et al.* 1980). Under the traditional cereal-cultivated fallow rotation regime of the Mediterranean region, it is thought that there have been large losses in soil fertility and organic matter over time. Harris *et al.* speculate that the contemporary Mediterranean soils, which have been farmed for many centuries, represent a nutrient depleted equilibrium (Harris *et al.* 1991, 241). When crop residues are largely or completely removed (e.g. by stubble grazing), infiltration of water is usually reduced, organic matter and soil nitrogen levels are lowered and crop productivity declines over time (Bolton 1991, 43).

Although Mediterranean soils may be 'depleted', a cereal-cultivated fallow rotation regime does seem to maintain a certain level of fertility (Loizides 1948). Cultivated fallow is also advantageous to soil moisture, but the amount of moisture retained for the next crop is highly variable and differs both from region to region and from year to year.

3.1.4 Factors Affecting the 'Success' of Cultivated Fallow

The different amounts of moisture conserved during a year of cultivated fallow are due to three main variables: precipitation, soils and tillage. First, as precipitation increases, the percentage of annual precipitation stored through the fallow period seems also to rise. Results from ICARDA's main station at Tel-Hadya (average annual precipitation 330 mm) showed that the proportion of precipitation stored ranged from 8% in a dry year to 37% in a wet year (Harris *et al.* 1991, 239). If precipitation in a fallow year is less than 200 mm, the penetration of that precipitation is only shallow, and very little, if any, moisture is stored for the subsequent year (Papastylianou 1991, 261).

The effectiveness of precipitation also depends upon the length, intensity and duration of the rainfall episodes; high intensity and/or widely spaced periods of rain provide little water due to high run-off and/or high evaporation compared with the same amount of water falling in slow, continuous rain (Papendick 1989, 26). In this context, it is interesting that most of the rain received in dryland regions most frequently occurs in only a few days (Dennett 1987, 48).

The second variable affecting soil moisture is the nature of the soil. Sands have a much lower capacity to hold water than silts or clays but have much higher infiltration rates (Papendick 1989, 266). French commented that in the semi-arid climate of south Australia, red-brown earths stored 10% of the year's precipitation and sandier soils only 2-3%, whereas black soils (with a high organic content) stored 20% of the season's precipitation (French 1963a, 47). Water conservation is more difficult on clay soils because the upward movement of water can continue at relatively high rates for a long time. As a consequence, more tillage is required to conserve moisture than on sandy soils (Papendick 1989, 266-267).

Depth of soil also affects moisture conservation. During the long dry Mediterranean summers, soils dry out to a depth between 300 and 400 mm. Only moisture stored below this depth will be useful for the next crop (Loizides 1979 in Papastylianou 1991, 261). Harris *et al.* extend this limit to the top 600 mm of the soil (Harris *et al.* 1991, 240). Consequently, deep soils have a higher water storage potential than shallow soils.

Finally, good tillage practices are vital to the success of cultivated fallow. The depth of tillage operations, the type of implements used and the timing of operations all influence the effectiveness of the fallow period. For the winter tillage episode, it is important that the surface is rough (Burwell *et al.* 1966 cited above) to allow maximum infiltration. During the spring episodes of tillage, when a soil mulch is being created in the upper levels of the profile, tillage of the top c. 300 mm of the soil will rapidly dry out the tilled surface but reduce evaporation from lower levels. The best way to improve infiltration and reduce evaporation using modern ploughing implements is discussed at length in the agricultural literature and often as part of the ongoing discourse on conservation tillage (for example, Guler *et al.* 1991; Jaradat 1988a, 223-233; Unger 1984, 107-146). For traditional tillage implements, however, the way these requirements can be achieved is reflected in Pinner's description of cultivated fallow (page 36). Widely spaced, shallow tillage before the winter rains aids infiltration and narrowly spaced, deep cross-tilling in spring creates a soil mulch which inhibits evaporation. (Incidentally, traditional tillage implements till to a maximum depth of between 250 and 300 mm (Unger 1984, 93).) Lastly, the timing of tillage operations is also critical as, for example, leaving weeds to grow on fallowed land, even for a short period, increases the amount of moisture lost. Thus early spring tillage followed by further repeated episodes benefits soil moisture.

Prolonging the length of the cultivated fallow period over more than one year does not appear proportionately to increase its value. First, winter storage is high because the soil is initially dry and there is a full complement of surface stubble which enhances infiltration and provides organic matter which can be mineralised into valuable nutrients. In a second winter, however, this stubble has either decomposed or been buried by tillage and storage and nutrient fixation is consequently reduced. Fallow efficiency, therefore, generally decreases as the length of the fallow period is increased (Papendick 1989, 264). Two year fallows do, however, take place in regions receiving low levels of precipitation (less than c. 250 mm) where the small amount of moisture retained would seem to contribute significantly to the success of a following cereal crop (Janssen 1972, 259).

3.1.5 The 'Thrice-Ploughed Field' (Short Fallows)

Unirrigated summer crops can be grown in the summer months of a fallow year. Summer crops include plants such as courgette, watermelon, green beans, okra, and millet. They are normally planted in April after the soil has been tilled and/or harrowed three times beginning in the late winter and early spring. This phenomenon is the 'thrice-ploughed field', or 'thrice-ploughed fallow', that is well known from classical antiquity (Forbes 1976; Semple 1932, 386). Summer crops survive on moisture retained below the dry soil mulch created by the repeated tillage operations.

The results of Samieh and Battikhi (see 3.1.3) suggest that although moisture is used by a summer crop - watermelon in their experiment - moisture is still conserved for the following crop (Saimeh & Battikhi 1985, 86). In a separate study, conducted by ICARDA at Tel Hadya in northern Syria, watermelon used 145 mm of soil moisture stored from the preceding winter. Over the summer months, 88 mm of moisture evaporated from bare fallow where no summer crop had been cultivated (Harris *et al.* 1991, 240). This means that approximately 40 % more moisture was conserved in soil that had not been cropped. Summer crops, therefore, deplete soil moisture; but under good conditions (see below), some moisture will still be retained for the next crop. Different summer crops have varying moisture requirements (for example, see table 3.1) and therefore, variation will exist in the quantity of soil moisture removed.

Harris *et al.* classify fallow with summer crops as 'short fallow' and fallow without summer cultivation (bare fallow) as 'long fallow' (Harris *et al.* 1991, 238). Short fallowing generally requires greater than c. 350 mm annual precipitation (Pala 1991, 94), whereas long fallowing takes place in drier zones, often with less than 300 mm annual precipitation (a barley-fallow rotation regime tends to dominate in these areas). Where summer crops can be supported, they are currently favoured by both farmers and agronomists because a crop is grown every year.

3.1.6 'Weedy Fallow'

During 'weedy fallow', no tillage takes place during the fallow year and, as a result, weeds flourish. Weedy fallow is particularly well known for North Africa where the weeds provide valuable grazing for livestock (Harris *et al.* 1991, 238). It also appears to occur more commonly in drier areas of the Mediterranean (less than 300 mm annual precipitation). Unfortunately, there is no Mediterranean based data available that allows for precise assessment of the effect of weedy fallow on soil moisture. The above discussions, however, would suggest that the amount of soil moisture conserved must be reduced through the transpiration of water by weeds and because a compacted soil surface reduces infiltration, promotes run-off and enhances evaporation. One early study conducted under semi-arid conditions in Australia would seem to support this: 65 mm of moisture was conserved under weedy fallow compared to 110 mm under bare fallow (Sims 1977, 245). Unfortunately, it is not specified whether the weedy fallow was grazed. From this experiment, some moisture does seem to be conserved - incidentally, it is as much as was conserved after cultivating watermelon in the experiments conducted by ICARDA (quoted in Harris *et al.* 1991, 240) and Samieh and Battikhi (1985). With so little evidence, however, it is impossible to generalise. Furthermore, the effectiveness of weedy fallow, as with cultivated fallow, will depend upon precipitation levels, soil type and soil depth as well as the extent to which weed cover is 'controlled' by grazing or cutting.

3.2 Cropping Patterns

Crops are rotated to maintain yields. A wide variety of crop rotation regimes, or cropping patterns, are practised in the Mediterranean region. Fallowing has traditionally been a key component of Mediterranean crop regimes due to its ability to restore soil moisture and fertility for the next crop. Precipitation is usually accepted as the principal limiting factor affecting the choice of a cropping pattern.

3.2.1 Common Crop Rotation Regimes

The major recent 'traditional' rotation regimes of the Mediterranean semi-arid region are listed below (compiled from: Arnon 1972a, 462-464; Elezari-Volcani 1930, 29-30; Forbes 1982, 221-226; Keatinge *et al.* 1985; Pinner 1930, 49-54):

2 course rotation regimes	cereal - weedy fallow
	cereal - bare fallow
	cereal - fallow with summer crops
	cereal - winter legume crop
	cereal - 'green manure'
	cereal - cereal (wheat- wheat; wheat-barley; barley-barley)
3 and 4 course rotation regimes	wheat - barley - bare fallow
	wheat - legume crops - barley - bare fallow
	legume crops - cereal - fallow with summer crops
	wheat - legume crops - fallow with summer crops
	wheat - fallow with summer crops - fallow with summer crops

Two course rotation regimes where a year of cultivated fallow (with or without summer crops) follows a cereal year, is the dominant 'traditional' rotation regime of the region (Charles 1990, 47; Cooper & Gregory 1987, 56; Helburn 1955, 380-381; Janssen 1972, 248; Loizides 1948, 210; Pinner 1930, 49-54). Bare fallow is, however, more common than fallow with summer crops. According to Pinner, wheat is 'always given the most favoured place in the rotation' (Pinner 1930, 54) or, in other words, comes after the most 'restorative' phase in the sequence (normally fallow). In traditional farming systems, a cereal-winter legume regime is much less common than a cereal-fallow rotation regime. As an exception, however, Forbes oberved that in Methana (Greece), legume crops were commonly rotated with cereals (Forbes 1982, 222). Two, three and four course rotations where a crop is planted every year (including fallow with summer crops) are referred to as 'continuous cropping' regimes in the agricultural literature. In this study, 'continuous cropping' refers specifically to the cultivation of winter crops every year.

3.2.2 Precipitation and Crop Rotation Regimes

The major natural environmental factor affecting the choice of a cropping sequence (rotation regime) is precipitation. Many crops cannot be cultivated at low precipitation levels and, therefore, their inclusion within a cropping sequence is impracticable. The minimum water requirements for some of the region's major crops are listed in Table 3.1.

The lower limits of cereal cultivation lie between 200 and 260 mm average annual precipitation. Under these circumstances, only barley is recommended for cultivation.

Above 260 mm, wheat can be cropped every alternate year, with bare fallow in the 'off' year (Janssen 1972, 259).

Above 350 mm average annual precipitation, regimes where a crop is cultivated every year (for example, wheat-legume or wheat-fallow with summer crops) can be employed (Cooper & Gregory 1987, 57-58; Harris *et al.* 1991, 238). Above 400 mm highly complex rotation regimes are possible (Arnon 1972a). At these relatively higher precipitation levels, the greatest diversity of rotation regimes has been observed. For example, Nordblom, in a survey in the Idleb province of northern Syria, noted that there were 24 different crop rotations practised in areas of relatively high annual precipitation (c. 340-580 mm) but only 10 in drier areas (c. 250-330mm) (Nordblom 1987, 15). Two and three course rotations were reported from the wetter areas, while the two course cereal-bare fallow rotation predominated in the sample from drier areas.

Soil depth also affects the suitability of a rotation regime to an area. Shallow soils, generally less than 600 mm, tend to be less able to support complex crop rotation regimes than deeper soils where moisture can be retained low down in the soil profile.

3.2.3 The Effect of a Preceding Crop on Cereal Yield

The cultivation of any crop has a profound effect on the soil and will, therefore, have repercussions for the following crop. First, a crop removes soil moisture through transpiration. In a Mediterranean environment, stored moisture can be very important and the removal of that moisture may result in reduced yields or even crop failure. Secondly, crops deplete precious soil nutrients. Mediterranean soils, especially those with a long history of cropping, are well-known for their low fertility; nitrogen and phosphorous are at a particular premium (Buddenhagen 1990, 11). Legumes, however, can provide their own nitrogen. Cultivating legumes in a rotation sequence has long been considered advantageous due to their ability to fix nitrogen by symbiosis with *Rhizobium* bacteria (Papastylianou 1990, 39). Measuring the yield of the following cereal is a direct way of assessing the impact of a preceding crop on the moisture and nutrient regime of the soil.

Littlejohn undertaking experiments in Cyprus (average annual precipitation 300-375 mm), noted wheat responses to different preceding crops over a five year period (Table 3.2). Green manuring produced the highest returns, followed by bare fallow, a legume crop, and lastly, wheat. Green manuring is the practice of tilling a legume into the soil before flowering and fruiting. In Littlejohn's experiment, wheat yield after a harvested legume crop was lower than after bare fallow. In this case, the better yield achieved after bare fallow is probably explained by the extra amount of moisture conserved within the soil during the fallow. The best yields were achieved after green manuring.

This is because when a legume is allowed to fruit, much of the nitrogen fixed by the legume crop is deposited in the fruit, and a large proportion of the extra nitrogen synthesised will be largely removed with the harvest (Mendel & Kirkby 1978). Cultivating a legume crop before wheat, however, produced better yields suggesting that some nitrogen is being added to the soil which will benefit the following crop. Thus overall, in this experiment, bare fallow is beneficial for soil moisture but legume culitvation is beneficial for soil nitrogen.

In a similar experiment, the effects of seven two course rotations have been tested at ICARDA's Tel Hadya station (average annual precipitation 330 mm). Over four seasons (1985-89), wheat yield after cultivated fallow (with or without the summer cultivation of watermelon) was consistently higher than after any other treatment (i.e. crop) tested. Vetch (*Vicia sativa*) and lentil were then ranked virtually together followed by chickpea, medic (a forage legume), and finally, wheat. Only in a wet year did total dry matter yields of wheat after vetch and lentil match those gained after cultivated fallow. This would suggest that some of the ranking can be explained almost entirely by the water balance of the rotations (Harris 1989, 145). These results emphasise that fallow is valuable to the next crop because of the moisture stored in the soil.

In an experiment carried out by Papastylianou in Cyprus testing legume-barley against continuous barley cultivation, legumes significantly improved the following barley yield. In fact, barley after vetch yielded as much as continuously cropped barley supplemented with 60 kg of nitrogen fertiliser per hectare (Papastylianou 1988, 61). This would seem to emphasise that legumes are valuable to the next crop because of their ability to help to maintain soil fertility.

Although cropping a legume before a cereal is more beneficial to soil nitrogen than continuous cereal cropping, there is still no clear answer as to whether it is more advantageous to the following crop, in terms of soil nitrogen, than cultivated fallow. In Cyprus, further experiments conducted by Papastylianou (1988) investigating the quantity of nitrogen fixed by legume crops showed that 50% to 80% of the plant biomass nitrogen came from fixation (Table 3.3). This means that 50% to 20% of nitrogen must be derived from elsewhere, or in other words, the soil - thereby leaving a nitrogen deficit. A following cereal crop would then have less nitrogen than if the land had been fallowed (Buddenhagen 1990, 15). This does not, however, take account of rained-in atmospheric nitrogen (both during the fallow and for the legume crops).

Cooper (1991, 144) has recently summarised the following sequence of availability of nitrogen after bare fallow and some common Mediterranean crops:

bare fallow > faba bean > summer crop > lentil >
chickpea > weedy fallow > cereal

Bare fallow appears, therefore, to benefit both soil moisture and soil nitrogen. Experiments on the advantages of cereal-legume rotation regimes are still, however, at an early stage and the results are equivocal (Jaradat 1988b, 283; Saxena 1988, 16). Cereal-legume rotation regimes appear dependent upon the local precipitation regime as well as the type of legume cultivated. For example, forage legumes (e.g. medics) are potentially more beneficial than cultivated fallow in regions receiving low amounts of precipitation. Yields can also be dramatically improved in cereal-legume rotation regimes with the addition of fertilisers or manure which maintain or improve soil phosphate levels (cf. Littlejohn 1946, 36). There has, furthermore, been little assessment of the long-term cumulative advantages of practising cereal-legume rotation regimes in the Mediterranean. Improvements in yield, soil fertility and soil stability in the semi-arid regions of Australia, where cereal-legume rotations have been practised for many years, demonstrate the longer-term potential for legume based regimes in the Mediterranean region (Buddenhagen 1990, 17; Chatterton & Chatterton 1984). This would appear to be the critical point.

For the short term, however, current research indicates that cultivated fallowing is more advantageous for the following wheat crop than a legume and that this is largely due to the improved water balance in the soil after fallowing. Significantly, however, a crop is produced every year in cereal-legume rotations instead of only every second year when bare fallow is practised. Combined productivity is, therefore, higher in cereal-legume than in cereal-fallow rotation regimes and considerably more than in the case of continuous cereal cultivation. The long-term advantages of cereal-legume rotation are also very promising. For a single wheat crop, green manuring produces the highest yields.

3.2.4 Adding Manure/Fertiliser

Manuring and/or applying fertilisers dramatically increases crop yields. For example, between the 1930's and 1950's in experiments conducted in Cyprus, fertilisers (or manuring) produced more every year than traditional bare fallowing in alternate years (Littlejohn 1946; Loizides 1958, 25-33). In recent years, chemical fertilisers have revolutionised agricultural practice and have been partially responsible for the dramatic increases in yields experienced in many countries.

'Traditional' sources of fertiliser, such as plant matter and manure, provide not only essential minerals but also organic matter to improve the physical structure of the soil and, therefore, its water-holding capacity and stability. The long-term value of manure is illustrated by the famous Broadbalk experiment at Rothamsted begun in 1843, where loss of nitrogen from the soil under manured barley is 3% compared to 30% for mineral manure and 40% when nothing was added. No organic carbon has been lost from the plot compared to 28% (mineral manure) and 40% (no fertiliser) respectively (FAO 1982).

Different types of manure contain different quantities of minerals. Cow dung for example, contains 1-2% nitrogen (N), 1-2% phosphorous (P) and 0.8-1.2% potassium (K) and human night soil averages 3-5% N, 2-4% P and 1-2% K. Wheat straw composted for 30 days can provide 31% organic carbon, 1.6% N, 0.3% P and 2.3% K (Abdel-Ghaffar *et al.* 1960, in FAO 1962). Sheep manure, perhaps the most common source of manure in the Mediterranean and Near East regions, provides 1.25% N, 0.5% P and 1.25% K (Littlejohn 1946, 128).

A well aggregated soil has an air moisture regime favourable for both plant growth and microbial activities. It has been shown that aggregate stability usually increases when soils are amended with organic materials and the short-term aggregating power of such materials is related directly to their rate of decomposition. In general, the rate of decomposition is legumes > cereal > FYM (farmyard manure) (FAO 1982, 27). FYM increases the phosphorous content in soils whereas wheat straw decreases phosphorous in the early stages of decomposition. As a consequence of the decomposition sequence, legumes usually have the most immediate effect upon soil aggregation and fertility. This would also partly explain the great value of green manuring. For soil fertility, much of the value of FYM results from the cumulative effects of one dressing after another on the structural improvement of the soil (Mendel & Kirkby 1978, 271) rather than its immediate provision of soil nutrients.

Supplementing crops with fertiliser or manure increases yields above those achieved after bare fallow. Fertilised crops enable more water to be extracted from greater depths in the soil profile due to improved root growth (Brown *et al.* 1987; Cooper *et al.* 1987). So, the appropriate addition of fertilisers also improves 'water use efficiency' (see below). Too much fertiliser can, however, be detrimental to wheat yield as fertilisers may promote more growth than the available soil moisture can sustain until harvest (Arnon 1972a, 381). Fertiliser applications, therefore, have to be adjusted to the moisture regime under which the plants are expected to grow.

3.3 Eliminating Cultivated Fallow

3.3.1 The Traditional' Value of Cultivated Fallow - A Buffer

From experimental data, cultivated fallow (and particularly bare fallow) not only restores soil moisture and enhances soil fertility, but it also seems to act as a valuable buffer against the severe annual variations in precipitation experienced in the Mediterranean region. It has been observed that the greatest value of bare fallow occurrs when a wet year is followed by a dry year (Harris 1989, 151). Thus, soil moisture stored during the fallow period compensates for the shortfall in precipitation experienced during the dry year. Even small amounts of moisture stored from a preceding fallow year can make the difference between success and failure for the following cereal crop. During a run of two wet years, on the other hand, stored moisture may not be required but this is difficult to forecast precisely at the start of the season. If farmers wish to ensure, rather than maximise, annual cereal production, bare fallow is the most 'secure' option to choose. There are, however, other ways (e.g. planting extra wheat/barley and storing it to cover a future shortfall) to ensure cereals are available for the next year.

3.3.2 The Agronomic Perspective

Despite the apparent ability of bare fallowing to conserve soil moisture, it is not promoted by agronomists as a practice suited to contemporary farming needs. The main criticism is that no matter how much moisture is conserved for the next crop, water is still lost during the fallow year and this lost water could be used to produce another crop. This is considered particularly inefficient as water is almost always the main limiting factor in dryland agriculture (Godwin 1990, 67). In agronomic terms, bare fallowing does not have the highest 'water use efficiency' (Harris *et al.* 1991, 239-240), i.e. the ratio of yield per unit area to water used to produce that yield (Gregory 1991, 9). With the burgeoning human and animal populations of the region, and the consequent demand for more food and fodder, it is increasingly considered as a practice that can no longer be afforded (van Schoonhoven 1991; Harris *et al.* 1991). It is now necessary to produce a crop every year. Cultivated fallow with summer crops is viewed as less undesirable (because a crop is produced) but cereal-legume rotation regimes are generally considered more advantageous.

In addition to lost production, cultivated fallow systems are viewed as detrimental to long-term soil fertility as well as encouraging erosion. Nutrients are depleted through cropping and the minimal application of manures under traditional Mediterranean crop management regimes means that soils maintain a comparatively low level of fertility thus limiting potential production. In addition, cultivated fallowing leaves soil susceptible to erosion and a depleted soil resource is one of the major problems facing semi-arid areas. Cultivating a legume in place of fallow is currently being promoted as a way both to improve soil fertility, through the nitrogen fixing ability of legumes, and provide a vegetative cover which protects soil from erosion (Harris *et al.* 1991; Jaradat 1988b; Osman *et al.* 1990). Forage legumes are being developed for areas with low annual precipitation (less than 300 mm) and crop, or food, legumes are being promoted for wetter areas.

Finally, agronomists point to the fact that, through chemical fertilisers and mechanised ploughing techniques, two of the major constraints that have previously limited continuous cropping - lack of nutrients and insufficient labour to plough - have been removed. Continuous cropping, especially in a rotation regime that includes legume crops, is promoted as a more productive, i.e. 'water use efficient', solution to the problems of the arable sector of the Mediterranean and Near East.

Recommendations for crop rotation regimes considered appropriate for different land capability classes and climatic zones in Jordan have been outlined (Watkins *et al.* 1983 quoted in Jaradat 1988b, 292). For areas receiving over 300 mm annual precipitation, these recommendations focus on wheat-legume and wheat-legume-summer crop rotations, although on slopes above 15%, only the two course rotation is advised. In the range between 200 and 300 mm, wheat with a fodder hay crop (vetch rather than lentil) is preferred. In line with the general tree planting policy, areas with high precipitation and sloping land are recommended for olives and, at high altitudes and/or high precipitation, for vines.

3.3.3 Replacing Fallow with Legumes

Despite the advantages of introducing legumes into a rotation regime and improvement in agricultural technology, fallowing (bare fallow and fallow with summer crops) continues to be practised in many parts of the Mediterranean and Near East. There are practical advantages of cultivated fallow, other than its ability to act as a buffer, which result in its continued use: weed problems are minimal, seedbed preparation is eased and disease is controlled. There is additionally the concept of a clean tilled surface representing 'good' agricultural practice and, therefore, a 'good' farmer (Bolton 1991, 43).

Breaking weed and disease cycles has proved to be a very important factor limiting the total replacement of fallow (for example, Harris *et al.* 1991, 246). Rotation of crops and cultivated fallow both contribute to the reduction of infestation, but problems arise where successive crops are susceptible to the same pest. Weeds are known to increase under cereal-legume rotation regimes (and even more so under continuous cereal cultivation), and the problem is normally exacerbated by adding fertilisers or manure. Disease and weed infestation remain two of the main problems facing agronomists.

In Jordan, there are numerous projects investigating the replacement of bare fallow by legumes, and cereal-legume rotation regimes are actively encouraged by all the major local organisations (Haddad & Snobar 1990, 80-81). Farmers have been replacing fallow with medics or a forage mixture especially in the central part of Jordan, such as in the Madaba region, where livestock production is an important component of the farming system (Sawafta 1985 in Haddad & Snobar 1990, 79). The most serious problem facing the production of legumes, however, is seen as harvesting which has not yet been successfully mechanised and is, therefore, still carried out by hand, a process accounting for more than 50% of total production costs (Haddad & Snobar 1990, 80). Legume-cereal rotation regimes, therefore, have a relatively high cost in labour. As the intensity of agricultural production increases, not only is labour required to apply a continuous cropping regime (legume or cereal) but also further attention is required for good crop maintenance, e.g. weed removal (Halstead 1987, 82). In addition, this labour, especially in the case of sowing, is required at a high stress period of the agricultural cycle when cereal crops are being established.

3.4 Contemporary Crop Rotation Regimes in Jordan

The recent *Wheat Baseline Data Survey* (el-Hurani 1988, 34) includes a survey of crop rotation regimes practised across a range of precipitation zones by wheat farmers in Jordan. The results are illustrated in Fig. 3.2.

Cultivated fallow is still widely practised in contemporary Jordan and is an important component of current rotation regimes. Cereal-bare fallow is the main rotation regime (87%) used in areas receiving less than 300 mm average annual precipitation. Between 300 and 400 mm, half the land being fallowed (39%) as part of a two course rotation regime is planted with summer crops. The wheat-lentil rotation is only practised by 5.4% of all the combined precipitation groups.

Above 400 mm, three course rotations (wheat-lentil-fallow or wheat-lentil-summer crops) represent 55.6% of the total. In the intermediate precipitation range (300-400 mm), rotations are more evenly divided between two and three courses at 47.6% and 45.6% respectively. As noted for the Idleb province in Syria (Nordblom 1987) discussed above, three course rotations are more prevalent in high precipitation areas. Finally, it is interesting that, in the lowest precipitation range, 42% of wheat growers practise continuous cereal cropping - either wheat-wheat or wheat-barley (this survey does not include barley-barley rotations) and 8% of farmers in the highest precipitation zone continuously crop wheat. Continuous cultivation of cereals, results in significant reductions in yield and would appear to be counter-intuitive, especially at the lowest precipitation levels.

Whilst precipitation levels provide a broad guideline for the crop rotation regimes that can be practised in Jordan (and the Mediterranean region), it is evident that precipitation, although exercising a powerful influence, does not dictate any one specific rotation regime that should be employed. Above 300 mm, more precipitation primarily seems to provide more options to the farmer and some of the rotation regimes practised do appear to be counter-intuitive. Other important factors must, therefore, influence a farmer's choice of crop rotation regime.

3.5 Summary

Cultivated fallow, and particularly bare fallow, does seem to improve soil fertility and moisture. In a traditional farming system, this capacity may have been an important buffer to the dramatic year to year variations in precipitation that can be experienced in the Mediterranean. Recent research, however, has highlighted that production can be significantly increased by including legumes in a rotation regime and/or adding fertilisers or manure. This type of continuous cropping could also have been practised in the past. Implementing these more intensive regimes under present day conditions, however, has highlighted that they require more labour (to sow and weed) and more resources (seed and manure) to implement. These observations have implications for the interpretation of 'traditional' and ancient management regimes (Halstead 1987).

Finally, contemporary farmers can be opportunistic on a year to year basis in the crops they plant (Nordblom 1987) and crop rotation regimes do change over time (for example, Jones's observations in Syria (1991, 197)). Both these latter points underline the observation that other factors must influence the choice of rotation regime and that, additionally, cropping patterns should not be viewed as static either in the past or present.

Chapter 4 Methodology

Three distinct methodologies are outlined in this chapter. The first is ethnographic and is used to document contemporary crop management practices (chapter 5) and to explore agricultural decision-making (chapter 6). The second methodology is ecological and is used to examine the weed flora of arable fields. The information on crop management practices is brought together with the ecological data using multivariate statistical techniques - techniques which enable an assessment of the effects of crop management practices on weed composition (chapter 7).

4.1 Ethnographic Methodology

Participant observation is the traditional core of ethnographic fieldwork. It is the data gathering method used in this research to investigate crop management practices and agricultural decision-making. It combines the observation of and participation in day-to-day activities as well as informal interviews. Two years were spent conducting both the ethnographic and botanical field research in four periods between 1989 and 1992.

4.1.1 Participation - Interaction and Observation

In the first stage of fieldwork, I lived in village households. This served as an excellent introduction to local society, codes of conduct, and enabled me to learn much of the local agricultural vocabulary, and importantly, to take part in agricultural activities. In this situation, however, I was repeatedly made aware of the fact that I was not an impersonal observer (Clifford 1986, 13). My practical involvement in village life and access to certain domains of knowledge was both expanded and constrained by my status as a young unmarried woman (cf. Callaway 1992, 35). To begin with, the majority of my time was spent in the company of women. In general, although women are involved in the management of land and the processing of its products, they are not usually recognised as the primary decision-makers. Furthermore, in northern Jordan, women's involvement in agriculture is decreasing with increasing mechanisation. Having stated this, however, I was very fortunate that my primary hostess was a widow who owned and managed agricultural land and was considerably knowledgeable about local farming. She also took considerable care to introduce me to relatives who had life-long associations with the land.

My status as a single woman meant that many constraints were placed upon my movements. For example, I could not go out unaccompanied to collect botanical specimens and could only speak to people who were generally approved of by my hosts. As I was a guest, it was inappropriate to go against my hosts' wishes too radically and I became reconciled to the fact that I was being treated as an 'honorary daughter' and did, therefore, respect many aspects of this role. As a 'daughter', I accepted I was being 'protected' - although the boundary between protection and restriction was often frustratingly difficult for me - and instead, I concentrated on the fact that within family circles I could take part in a wide range of activities. It was easy to be involved with domestic chores (for example, food preparation) in and around the home. I did, however, have to insist quite forcibly that I did want to do manual agricultural work. On reflection, I realised that, although I was a 'daughter', I never totally lost my position as a guest. I could, consequently, put my hosts in a socially unacceptable position by working. This was overcome to some extent when I did work because people generally appreciated the effort I expended even if the skill was not great! The family could then take some pride in my 'strength' or tell amusing stories about my failures. It also added real weight to my statement that I wanted to learn about farming and particularly endeared me to many members of the older generation who complained that the younger generation were not interested in the land. My interest also seemed to be viewed as an expression of 'modesty' although people were often very amused, or bemused, by the apparently trivial nature of the details I required.

The final obstacle encountered whilst living in a household centred around note-taking. Taking notes in front of your host, or 'informant', is immediately divisive: it emphasises the relative positions of interviewer and interviewee. Furthermore, it breaks up the flow of ideas during a conversation. Even writing-up notes privately at a later juncture proved a problem because I was simply never alone. Writing in front of people not only makes them uncomfortable and suspicious but also constantly reinforced to all concerned my position as an outsider. I tried to overcome the suspicion by conspicuously filling my notes with local agricultural terms and by occasionally asking people to write down spellings or to illustrate an observation with a sketch. In this way, I tried to make my notes less of a mystery. On the other hand, the fact that I tried to keep note-taking to a minimum could also occasionally work to my disadvantage as people would suggest that I was not taking them seriously, or that I was not a serious student, if I did not take notes whilst they were speaking!

It is commonly stated that, as a foreign woman, you become an 'honorary man' in Arab society. I found that this was not the case whilst actually living in a household except for one important exception: I was allowed, under supervision, to talk to some of the older farmers in the village. My status seemed to approach that of an 'honorary man', however, when I was an occasional visitor or encountered farmers working in the fields. It is significant that the only occasion when I was offered the opportunity to plough, an exclusively male task, was during such a chance meeting. As a young unmarried woman, however, it appeared that I could not represent an authoritative figure in the same way as a man. This could work both to my advantage and disadvantage and although I usually met a warm response and was generally considered beyond suspicion (or at least less so than a man would have been), a few men did not consider it appropriate to talk to me (this was probably also the result of a particular religious sentiment). I retained throughout, however, the ability to talk to women - something that I could not have done as a man.

After the initial period living with people, I placed myself in a more independent position by living either independently or with local friends in Irbid. I then visited families in the villages or, especially during the period of botanical sampling, encountered people working in their fields. At many points in my fieldwork, I would take a friend along to help. These friends were usually my contemporaries in age and generally represented the sons or daughters of some of the region's well-known local families. They would often take me to visit relatives who farmed, would introduce me to farmers recommended by their families or at least suggest likely areas where I could find something to interest me. Being introduced to farmers did a great deal to ease conversation and helped to endorse my interest in farming.

Throughout my fieldwork, discussions and observations about agriculture formed only one part of my interaction with people - it was both important and enjoyable to be involved in many other aspects of life. So, for example, I attended weddings, paid social calls to relatives, and watched Egyptian soap-operas on television (a great topic of conversation)! I was also privy to many private conversations between older members of the family and, because of my position as outsider, found people, usually women of my own age-group, explaining the many complexities of their family lives to me. It was also true that even when I was trying to conduct an informal interview, I found myself at least as much the interviewee as the interviewer!

Whilst living with families, in particular, I was impressed by the fact that crop management cannot be divorced from the social context of the people who farm the land. The situation of the household has a profound effect on the way the land is managed. Equally, lives are paced to the requirements of the land and at harvest time, for example, most of a family's labour can be expended securing the crop. This early experience particularly highlighted the role of decision-making in crop management and helped me to formulate the questions which formed the basis of the interviews.

4.1.2 Interview Methodology

The interviews were conducted on an informal basis and, in practice, took many forms. Some interviews were conducted over a number of visits to families who were particularly well-known to me whilst other interviews represent one-off visits or chance encounters with farmers working in their fields. It has already been observed that note-taking during conversations tends to interrupt the flow of thought and acts as a barrier. So, after an initial period of experimentation, interviews tended to be conduced in a conversational manner and notes would be written-up later.

Farmers are notoriously reticent to divulge information (cf. Forbes 1982, 10) and I was never very successful at procuring figures for yield or profit except in terms of broad estimates. In terms of recording views on crop management my most common problem was not that people refused to divulge information but that they tended to press their opinion upon me even when they had no practical experience of the issue under consideration. More disturbingly, people also tended to try to tell me the answers that they felt I wanted to hear. I constantly found myself questioning statements and trying to understand the motives behind various assertions. For example, whilst sampling fields for weeds, one crucial question was, 'have you used weed-killers?'. People often replied positively even when weed-killers had not been applied because, I supposed, they wanted to appear 'modern' (perhaps they were more used to talking to agricultural extension workers). I once caused a small argument between a husband and wife because he insisted that he had hand-weeded the field alone and she that they had applied weed-killer together. When people discovered that I wanted them to have weeds in their fields, they rapidly changed their assertions. Ultimately, questions had to be phrased very carefully to ensure that there was the least possible concept of a 'correct' response. Another way to discover a more reliable story was to talk to a number of people at once and through the banter a coherent picture emerges - but not always!

During 1992, the aim of the fieldwork was to look at past decision-making, and particularly, the role of <u>mushā'a</u> (communal farming). Interviews were conducted with some of northern Jordan's oldest inhabitants. In total, over 30 men and women were interviewed from 17 different villages in the hills and on the plains. The two oldest members of the group interviewed in 1992 claimed that they had been included in the Ottoman land registration conducted in the 1880's and, indeed, one still possessed his registration documents. The information derived from these interviews, as with the contemporary decision-making study, requires critical evaluation especially as the facility does not exist to verify many of their assertions with direct observation. Memories can be distorted and it is also often difficult to assess the time period being discussed. People can also idealise the past or exaggerate the importance of their village or family. In general, however, I was repeatedly and overwhelmingly impressed by the freshness of people's recollections and the reassuring consistency of the accounts.

4.1.3 The Farmers Interviewed - The Nature of the Study Group

In general, the farmers interviewed who formed the study group conformed with the following conditions. First, the area of land that is owned or rented is less than 50 dunum (just over 12.3 acres or 5 hectares), and in practice is usually between 20-30 dunum (between 5 to 7 acres or 2-3 hectares). Secondly, for most farmers, the majority of produce is intended for household consumption. Thirdly, very little labour is employed from beyond the immediate or extended family. Finally, there is limited use of mechanised farming equipment or agro-chemicals. On the plains, however, tractors are almost ubiquitous, although for many small-scale farmers, they represent the main single aspect of 'modern agricultural practice' included in their farming routine. The farmers interviewed, therefore, do not represent a random selection of practising farmers in the region but rather encompass a selection of small-scale farmers who, for the majority of purposes, use what might be termed 'traditional' farming methods.

Most of the farmers interviewed were derived from the older generation. This, however, seems to be a true representation of the age groups that are currently practising agriculture in Jordan. For example, in the wheat baseline data survey, nearly 75% of the randomly sampled dryland wheat farmers were over 50 years old (el-Hurani 1988, 1).

4.1.4 The Interview

The interviews provide the 'cultural' variables in the ecological analysis (chapter 7) and are the basis for the discussion on agricultural decision-making (chapter 6). There are two groups of 'cultural' variables: the first group contains details on the way fields are cultivated (crop management practices), and the second includes information about the people who cultivated them (the farming background).

4.1.4.1 'Cultural' Variables - Crop Management Practices

The history of recent cultivation was compiled for each field. Questions were asked about the field's cropping history to ascertain if there was a normal rotation regime. For the current year of cultivation, estimates of the sowing rate and sowing date of the wheat crop were also recorded. In addition, the type of tillage implement used, whether any weeding had taken place, and if the field had been manured were noted. Details of the way in which this information was summarised for use in the computer-based analyses are given in section 4.3.3.1 and shown in Table 4.1a.

4.1.4.2 'Cultural' Variables - Farming Background

Details were taken about the main person involved with the management of the land and their household. Normally, but not always, the male head was responsible for taking most of the decisions relating to crop management. The data collected included the amount of land cultivated, the crops cultivated and the tenurial arrangement. Information about the farmer's age and past and present occupation was noted. The number of children in the farmers' families was also recorded and whether they were employed in crop management or if they held some other employment. Finally, the numbers and kinds of animals held by the household was noted. The information recorded was not restricted to the above factors but these details form the core of each interview. Details of the way farming backgrounds were summarised for use in the computer-based analyses are given in section 4.3.3.2 and shown in Table 4.1b. This information forms the basis of chapter 6 ('agricultural decision-making').

4.2 Ecological Methodology

4.2.1 Field Selection

The objective of the ecological fieldwork was to sample the weed floras of fields cultivated under two and three course rotation regimes from both the hills and the plains. Two further important criteria had to be fulfilled for farmers' fields to be included in the sample group. First, the field had to be cultivated with wheat and secondly, it must not have been treated with herbicides.

Many fields were sampled at the same time as harvesting as this was an excellent way to both locate the particular field, gain permission to examine its weed flora, and affirm information about the field's recent cropping history (and collect information about the farmers if they had not been previously interviewed).

4.2.2 Field Sampling

There were two periods of field sampling: the first took place between 1 May and 10 June 1990 and the second between 22 May and 15 June 1991. When sampling began in 1990, the wheat had just finished flowering and the legume harvest had not yet commenced. In 1991, however, the legume harvest was almost complete when the first field was sampled. In both years, fields were sampled until the end of the wheat harvest. In total, sixty fields were sampled. The locations of these fields are shown in Fig. 4.1.

The field methods employed were similar to those followed by G. Jones et al. (in press). The weed flora of each field was sampled along a transect starting just inside the field edge and extending either to the opposite field edge or up to 100 m into the cultivated area depending upon which came first. As fields could extend for more than 500 m (plots tended to be long and thin), the 100 m limit was imposed in an attempt to prevent the recorded 'environmental' variables from varying too grossly across the sampled area. The weed flora from ten quadrats (each representing 1 m^2) was sampled along the transect. Quadrats were placed at random intervals along the transect. A table of random numbers was used to calculate where each quadrat should be placed along the transect although the positioning of the transect itself was not assessed by the use of random numbers. Within each quadrat the presence of a taxon was recorded and its stage of development noted (Plate 4) according to the following four categories: vegetative, flowering, fruiting, and finally, flowering and fruiting. Numerous plant specimens were collected and pressed ready for later verification and refinement of field identifications. Within each quadrat, the height of the wheat crop and an estimate of the percentage cover of the crop was also recorded (see Table 4.1c).

4.2.3 'Environmental' Variables

A number of 'environmental' variables were recorded for each field. Together, the 'cultural' and 'environmental' variables are the external variables used in the multivariate analyses. The first 'environmental' variable is vegetation zone (as classified in section 2.4.2) which was determined from observation of the local flora. Secondly, altitude was calculated by reference to maps from the Jordan 1:50,000 series. Thirdly, if the field was on a slope, the position of the field on that slope, the steepness of the slope and it's aspect (for example, north or west) were also recorded. The stoniness of the soil was estimated as a percentage of stones covering the soil surface. Finally, a soil sample was taken from each field. The soil samples were later analysed for magnetic susceptibility, pH and organic content (see section 4.3). A full list of the 'environmental' variables is given in Table 4.1c.

4.2.4 Identification

Weed species were identified primarily using *Flora Palaestina* (M. Zohary & Feinbrun-Dothan 1966-1986) and by comparison to herbarium specimens housed at Jordan University, Yarmouk University and the Royal Botanic Gardens in Edinburgh. Other references used include Davis (1965-88), Karim & Quraan 1988, Townsend & Guest (1968, 1974, 1980), Post (1883-1896 and 1932), and finally, al-Eisawi's (1982) *List of Jordan Vascular Plants*. The nomenclature used in this thesis for 'wild' plants follows *Flora Palaestina* - which is the most comprehensive flora in existence for the study region. Within the genus *Papaver* L. (poppy), however, the nomenclature used for section *Rhoeadium* Spach follows Kadereit (1988).

The pressed specimens collected in the field represented nearly all states of each plant's development: vegetative, flowering and fruiting. By far the majority of specimens, however, were collected in their fruiting stage.

A full list of the taxa used in the botanical analysis is given in Appendix 4.1. The primary distinguishing criteria of taxa occurring in three or more of the sampled fields (i.e. present in at least 5% of the fields) are listed below. These criteria are not intended to be comprehensive descriptions of the taxa. All the families, genera and species are listed alphabetically.

4.2.4.1 Berberidaceae

Bongardia chrysogonum (L.) Sp. is a tumbleweed, i.e. the seeds are dispersed by the detachment of the entire fruit-bearing scape from its subterranean tuber. The leaves are very distinctive - all deeply divided with the end of the segments also divided into three to six lobes. The leaf segments are green but often have a reddish dot at their base. The yellow flowers sit on leafless scapes. In fruit, the capsule is membranous, torn at its apex, and contains one or two large black globular seeds.

4.2.4.2 Boraginaceae

Anchusa italica Retz. (Syn. *A. azurea* Miller var. *azurea*) is a perennial herb, c. 300 mm to 700 mm tall. Long stiff white hairs cover the plant's stem. The inflorescence is forked during flowering and lax at maturity. The calyx is c. 10 mm long (longer in fruit), covered with appressed bristles, and has sharp-pointed linear-lanceolate lobes which are divided nearly to its base. The corolla is deep blue or white and about as long as the calyx.

Anchusa strigosa Banks & Sol. is also a perennial herb, c. 400 mm to 800 mm tall. The stem is sparsely armed with prickles which have a comparatively large tubercule at their base. The calyx lobes are blunt and have a fringe of hairs along their edge and one row of bristles along the midvein. The flowering calyx is shorter than the blue corolla tube.

4.2.4.3 Campanulaceae

Campanula strigosa Banks & Sol. is a small annual which is covered in short stiff hairs. The calyx has ovate to lanceolate lobes which end in a point, c. 2 mm to 4 mm in length. The corolla is light violet and approximately twice as long as the calyx. The fruiting capsule is nodding and concealed by the calyx.

Legousia speculum-veneris (L.) Chaix is another small annual but it is glabrous or nearly so. The flowers are nearly sessile and usually found in terminal cymes of three to five. The calyx lobes are linear-lanceolate and shorter than the ovary. The capsule has three compartments, is constricted at its apex, and oblong-prismatic in shape.

4.2.4.4 Caryophyllaceae

The most characteristic feature of *Cerastium dichotomum* L. is the thin cylindrical capsule which has ten delicate nerves and is two to three times longer than the sepals. The sepals themselves are oblong-lanceolate with a pointed apex and, except for the tips, are covered in patulous glandular hairs.

Minuartia hybrida (Vill.) Schisch. is a tiny herb only 50 mm to 200 mm in height. The flowers are also small - the sepals are 2 mm to 3.5 mm long - and neither the white petals nor the capsule exceed the sepals in length. The sepals have three nerves and are generally glabrous.

The main plant part used to identify species of the genus *Silene* L. was the calyx.

The calyx of *Silene conoidea* L. has thirty nerves and is c. 15 mm to 20 mm in length. The lower part of the calyx becomes greatly inflated when the plant is in fruit but the apex is drawn to a point.

Silene crassipes Fenzl has a ten-nerved calyx, c. 10 mm to 15 mm long. The nerves are green and have conical papilae along them. The calyx is oblong in flower and club-shaped when the plant is in fruit.

The calyx of *Silene damascena* Boiss. et Gaill. is c. 20 mm long, ten-nerved and tinged with purple - especially along the nerves. The calyx is cylindrical but becomes an elongated club-shape when the plant is in fruit. It can be distinguished from *S. colorata* Poir. by its seeds: the seeds of *S. damascena* do not have undulate wings at their margins.

Silene vulgaris (Moench) Garke is the only member of the genus described here which is glabrous (or nearly so) and it is also the only perennial. The calyx has twenty fine nerves, is broad and bladdery, and has a green and violet hue.

Vaccaria pyrimdata Medik. is a glabrous annual. The calyx is prominently five-ribbed with five ovate-triangular teeth. The calyx ribs are green and contrast strongly with the rest of the calyx which is a greeny white. The capsule is ovoid or subglobular and contains numerous black subglobular seeds.

4.2.4.5 Convolvulaceae

All three species of *Convolvulus* L. described below are perennial herbs with long (up to 1 m) trailing and twining stems.

The lower middle leaves in *Convolvulus althaeoides* L. are cordate-ovate with crenate or lobed margins The corolla is pink or purple. The outer sepals are hairy and the ovary is glabrous or very slightly hairy.

Convolvulus arvensis L. has triangular or oblong-ovate leaves which have hastate or sagittate bases. The leaf margins are generally not lobed. The corolla is normally white or sometimes a very pale pink. The sepals and capsule are normally glabrous and the ovary nearly so.

Convolvulus betinicifolius Mill. is covered with yellowish hairs. It has ovate to oblong leaves with sagittate or hastate bases and the margin may be entire or dentate lobed. The corolla is white or cream-coloured. The sepals, ovary and capsule all have long fine hairs.

4.2.4.6 Compositae

In maturity, *Anthemis palestina* Reut. subsp. *palestina* (Syn. *A. melanolepis* Boiss.) has a large convex receptacle, c. 10 mm to 15 mm, which is a dark brownish-purple colour. The upper involucral bracts are tipped with a sharp rigid point. The achenes are brown, marked with 8 to 10 ribs on each face, and have a slightly elevated rim at the apex.

Anthemis pseudocotula Boiss. emend Eig. has a smaller receptacle than *A. palestina*, c. 5 mm to 75 mm in diameter, which is almost cone-shaped in maturity. The involucral bracts do not possess a point but the long receptacular bracts terminate in a short spine. The achenes are persistent and distinctly 10-ribbed.

Carthamus tenuis (Boiss. et Blanche) Bornm. subsp. *foliosus* Hanelt has white stems, grey foliage and is covered, especially around the head, with cobweb-like hairs. The cauline leaves are narrowly lanceolate, folded around the mid-vein, and have sharp teeth around the margins which are one third to one half the width of the leaf. The florets are pale violet with dark violet anthers. When broken, a deep red fluid seeps from the stems.

Centaurea hyalolepis Boiss. has whitish stems and branches. The heads are subsessile and subtended by the upper leaves. The outer involucral bracts end in a spreading yellow simple spine which is sometimes flanked at its base by one to three pairs of slender spinules. The florets are usually yellow.

The cauline leaves of *Centaurea verutum* L. are oblong and entire and extend down the plant stems forming distinct wings. The heads are solitary and the outer involucral bracts terminate in a spine which has a black base and spinules above its middle.

The stems of *Cichorium pumilum* Jacq. are slightly hairy or glabrous. The heads are either axillary or borne at the ends of thickened peduncles. The florets are large (two to three times as long as the involucre) and a striking sky-blue colour. The inner involucral bracts are 1.5 to 2 times longer than the outer bracts. The achenes are 2 mm to 3 mm in length and each have a short pappus which is made of minutely serrulate pales.

The fruiting heads of *Crepis aspera* L. are less than 15 mm in length and, in maturity, are strongly constricted above their middle. The inner involucral bracts are armed with prickles along their mid-vein. Usually, the achenes have a beak which is approximately the same length as the achene proper.

Filago pyramidata L. has erect stems which are covered with an appressed whitish grey indumentum. The heads are c. 10 mm in diameter and consist of 8 to 16 ovoid headlets. The paleas are keeled and gradually taper to a short awn. The achenes are tiny, c. 1 mm long.

Geropogon hybridus (L.) Sch. Bip. has a large solitary head with purplish pink florets. It differs from *Tragopogon* L. in possessing dimorphic fruit: the outer achenes are persistent, smooth or slightly rough to the touch and tipped with five rigid pointed scales. The inner achenes have a pappus of long plumose hairs.

Notobasis syriaca (L.) Cass. is an erect spiny annual herb. The upper floral leaves are reduced to pinnatisect branched spines which surround and overtop the heads. These leaves are purplish with silvery veins. The involucre is sparsely covered with cobweb-like hairs and the florets are a deep purple.

Picnomon acarna (L.) Cass. is covered with apressed cobweb-like hairs. The stems have continuous spiny wings. The leaves are leathery and pinnately lobed with each lobe ending in one or two long yellow spines - and between these larger spines are short spines. The florets are purple.

Picris sprengariana (L.) Chaix (Syn. *P. altissima* Delile) has leaves which form a rosette at the base of the stem. These leaves are oblong-lanceolate and have either entire or wavy-dentate margins. The inner involucral bracts are curved, keeled in fruit and have spreading bristles. The achenes are dimorphic: the outer achenes are curved and persistent whilst the inner ones are smaller, straighter and deciduous. Both inner and outer achenes are horizontally wrinkled.

Rhagdiolus stellatus (L.) Gaertnern was instantly identifiable by its curving achenes, up to 20 mm long. Each of the six to eight outer achenes is tightly enclosed by an involucral bract which is either glabrous or minutely setulose. The one to three inner achenes are much shorter and deeply incurved. The achenes do not possess a pappus.

The stems and leaves of *Scolymus maculatus* L. have white thickened margins. The stems have continuous spiny-dentate wings and all the leaves are also edged with spines. The heads are terminal and either solitary or in groups of two to three. The florets are yellow.

The cauline leaves of *Senecio vernalis* Waldst. & Kit. are sessile, half-clasping, oblong-lanceolate and variously lobed. There are up to 12 calycular bracts which are short, blunt, and dark-tipped. The involucral bracts are linear-lanceolate and have thin and dry margins. The achenes are c. 2 mm long with a pappus two to three times as long as the achene.

Urospermum picroides (L.) F. W. Schmidt was most often found in the later stage of maturity when the bristly leaf-like involucral bracts were folded downwards and only a few seeds were left on the receptacle. The achenes are very distinctive: they are up to 15 mm in length, have a smooth long beak (c. 10 mm long) and the lower portion is coarsely covered in small projections.

4.2.4.7 Cruciferae

The Cruciferae were distinguished largely on the basis of their fruits.

Cardaria draba (L.) Desv. has a laterally compressed silicula (a fruit less than three times as long as it is broad) which forms an inverted 'heart-shape'. There are two valves which are indehiscent, keeled and each contain either one seed or none. The style is persistent and rather long. The fruiting pedicel is approximately three times as long as the fruit.

Diplotaxis erucoides (L.) DC. has a long linear dehiscent siliqua (a fruit more than three times as long as it is broad) with flattened one-nerved valves. The partition between the valves is membranous and the seeds are very small. It is distinguished from *D. harra* (Forssk.) Boiss. by its white flowers (*D. harra* has yellow flowers) and the siliquae have longer beaks and stipes.

The siliqua of *Erucaria hispanica* (L.) Druce is two-membered: the upper part is ovoid, indehiscent and has a short beak (2 mm to 5 mm long). The lower member is cylindrical and has two dehiscent valves. Both parts are longitudinally nerved and usually approximately equal in length (or the lower part is slightly longer).

The siliqua of *Hirschfeldia incana* (L.) Lagreze-Fossat is closely appressed to the stem. The upper segment of the siliqua is slightly swollen, indehiscent and either sterile or one-seeded. The lower segment is linear, dehiscent and contains between three to nine seeds.

Neslia apiculata Fisch., Mey. et Ave-Lall. has an indehiscent one-celled fruit which contains just one seed. The fruit is more or less spherical, coarsely rugose and has a persistent style base that forms a small umbo.

Rapistrum rugosum (L.) All. has a silicula that is in two parts. The lower member is cylindrical and often only one-seeded. The upper member is globose, longitudinally ribbed or wrinkled, and ends in a beak (1 mm to 4 mm long).

Sinapis arvensis L. has a linear siliqua (up to c. 45 mm long) which has two dehiscent valves. The valves have three to five nerves and are either glabrous or sparsely covered in deflexed hairs. The siliqua has a straight indehiscent conical beak which is not strongly compressed and is most frequently shorter than the valve (these are two of the main characteristics which separate *S. arvensis* from *S. alba* L.).

4.2.4.8 Dipsacaceae

Cephalaria syriaca (L.) Schrad. has undivided cauline leaves with serrate margins. The head is ovoid, c. 12 mm to 30 mm long, and has bluish flowers. The receptacular bracts are ovate to oblong, have slightly membranous margins, and terminate in a long purplish awn. The fruiting involucel is 4 mm to 5 mm long and has four long and four short apical teeth.

4.2.4.9 Euphorbiaceae

Euphorbia aleppica L. was usually found in its vegetative state and is easily identifiable. The lower cauline leaves are linear or needle-shaped and fall off, leaving a distinctive scar, at a comparatively early stage of development. The floral leaves are rhombic to triangular in shape.

Euphorbia falcata L. has elliptic to ovate floral leaves. The capsule, and particularly the seeds, however, enabled this species to be identified. The capsule is c. 1.5 mm to 2.5 mm long, ovoid, and composed of three compartments. The seeds are tiny c. 1 mm, with a row of four to six transverse grooves on each of their four faces.

Euphorbia reuteriana Boiss. was also identified by its capsule and seeds. The capsule is 3 mm to 4 mm long and deeply grooved into 3 lobes. The seeds are c. 2 mm long, ovoid, deeply pitted, and each have a short conical caruncle.

4.2.4.10 Fumariaceae

Fumaria parviflora Lam. has short-peduncled dense racemes with up to 20 flowers. The sepals are minute - as broad as, or narrower, than the pedicels - and the corolla is white and tinged with pink or purple. The fruits are subglobular, wrinkled, distinctly keeled, and are either blunt or terminate in a short point.

4.2.4.11 Geraniaceae

Geranium rotundifolium L. has orbicluar leaves which are either segmented or formed into three to five lobes. The peduncles are usually two-flowered and the petals are pink, wedge-shaped, and c. 5 mm to 8 mm long. The mericarps have a glandular hairy beak that is 15 mm to 20 mm long. The seeds are regularly pitted.

4.2.4.12 Gramineae

Avena sterilis L. subsp. *sterilis* has a loose, almost one-sided panicle. The glumes have 7 to 11 veins, are sub-equal and c. 30 mm to 40 mm long. There are three to four florets per spikelet and the lower two or three are densely hairy whilst the upper ones are awnless and glabrous. At maturity, the rachilla disarticulates above the glumes so that the unit of dispersal is the spikelet without the glumes.

Bromus alopecuros subsp. *carolini-henrici* (Greuter) P. M. Smith has an erect spike-like panicle. The spikelets are usually borne singly at the nodes and are 20 mm to 40 mm long. The lemmas are glabrous to villose, oblanceolate, and have a deep apical notch which is flanked by tapering or triangular teeth. There is a single awn c. 15 mm to 25 mm long which is somewhat bent and spreading at maturity.

Bromus lanceolatus Roth has a rather dense, erect or sometimes slightly spreading panicle with one or two spikelets per branch. The spikelets are c. 20 mm to 40 mm long and have overlapping lemmas which are softly woolly. Each lemma has a single awn which is bent and spreading in maturity.

The panicle of *Bromus tectorum* L. is very distinctive - the crowded and nodding spikelets are all turned to one side. The spikelets are c. 30 mm to 40 mm long (including the awns), wedge-shaped, and each posses five to nine flowers. Both the glumes and lemmas have silvery, thin and translucent margins.

The inflorescence of *Catapodium rigidum* (L.) C. E. Hubbard is an erect rigid panicle with ascending branches and spikelets. The spikelets are 3 to 10 flowered, c. 1.5 mm broad and have a purplish hue. The lemmas are glabrous and have rounded backs.

Cynodon dactylon (L.) Pers. is a perennial with creeping stolons and scaly rhizomes that spread in all directions. The terminal inflorescence consists of three to six digitatively arranged straight spikes. The spikelets are small, c. 2 mm.

Lolium rigidum Gaudin has spikelets which are often appressed to the rachis, especially after flowering. The glumes are lanceolate-oblong, less than 20 mm long and not turgid in maturity. None of the lemmas possess an awn. The mature caryopsis is more than three times as long as it is broad.

The spikelets of *Lolium subulatum* Vis. are partly sunken into the rachis and are completely covered by the upper glumes. The spikelets have between two to four florets and only the upper ones have awns. The mature caryopsis is more than three times as long as it is broad.

At maturity, the spikelets of *Lolium temulentum* L. are very turgid. The mature caryopsis is more than three times as long as it is broad and the encapsulating lemmas are elliptic to ovate. The glumes of the lower and middle spikelets are 0.75 to 1.5 times as long as the spikelet. Incidentally, none of the collected specimens were identified as the morphologically close *L. multiflorum* Lam. although this species is also present in the region.

Lophochloa cristata (L.) Hyl. has a short, dense and spike-like panicle. The spikelets are c. 3 mm to 4 mm in length (excluding the awns) and consist of three to five flowers. The lemmas are sharply pointed, keeled and have a short straight awn. The paleas end in two short points.

Phalaris brachystachys has a dense ovoid or elliptical panicle, c. 15 mm in length. The inflorescence consists of both fertile and sterile spikelets. The glumes are c. 6 mm to 8 mm long and have a thin papery wing on their upper two thirds. The glumes are not toothed.

The panicle of *Phalaris paradoxa* L. Link is dense, oblong-cylindrical and c. 3 to 6 mm in length. The uppermost leaf-sheath is usually inflated and encloses the base of the panicle. The spikelets are in groups of five to seven but only the central spikelet is fertile. Each of the glumes of the fertile spikelets has a 2 mm to 3 mm awn-like prolongation at their tip and a tooth-like wing on the keel just below the prolongation.

4.2.4.13 Hypericaceae

Hypericum triquetrifolium Turra was most often found either in its vegetative or flowering state. It has a distinctive slender, widely spreading and pyradmidal form. The triangular-lanceaolate leaves have crisped wavy margins. The flowers are solitary and have yellow linear-oblong petals.

4.2.4.14 Iridaceae

The inflorescence of *Gladiolus italicus* Mill. is a two-sided spike. On each spike there are between six to sixteen showy pink flowers (*G. atroviolaceus* Boiss. has purple flowers and a one-sided spike).

4.2.4.15 Labiatae

Lallemantia iberica (Bieb.) Fisch. was only found in fruit. The verticillasters are numerous and clustered in groups of four to six flowers. The bracteoles are very distinctive: they are wedge-shaped and tipped with five to nine long aristate teeth. The calyces are tubular (the base is slightly expanded in fruit), fifteen-veined, and tipped with five comparatively short teeth. The nutlets are dark brown and ovoid-triquetrous.

Lamium amplexicaule L. has purple-tinged stems which branch out from the base of the plant. The leaf margins are broadly ovate and notched at the margins with round teeth. The terminal verticillasters are crowded together to form a 'head'. In its most common form, the corolla is purple and two to three times as long as the calyx. The corolla also has a distinctive undivided long upper lobe.

Salvia syriaca L. is tinged all over with yellow. The leaves have wrinkled surfaces and crenulate margins. The floral leaves are very short - barely longer than the short pedicels. The calyx is c.10 mm long, prominently veined, and each calyx tooth terminates in a short spine. The corolla is a cream or yellow colour and almost twice as long as the calyx.

Stachys arabica Hornem. has numerous verticillasters and each one contains four to six flowers. The floral leaves are sessile and triangular-lanceolate in shape. The calyx is c. 15 mm long and has spiney triangular-oblong teeth which are approximately one third as long as the calyx tube.

4.2.4.16 Leguminosae

Coronilla scorpiodes (L.) Koch was most often found in fruit. There are between 2 to 5 linear and slightly curving pods per raceme. The pods are strongly constricted between seeds (usually between 7 to 10 per pod) and readily break into segments when dried. Each segment is strongly four-sided and contains one narrowly cylindrical dark brown seed.

Lathyrus aphaca L. is instantly recognisable by its leaves which are reduced to tendrils and leaf-like stipules. Racemes are usually single flowered (with a yellow corolla). Pods can be up to 30 mm long and are oblong-linear and compressed in shape.

Lathyrus gorgonei Parl. has comparatively large leaves (up to 100 mm) and the leaflet pairs are oblong-lanceolate to elliptical in shape. Flowers are solitary and usually have a yellow corolla. The pod is situated at the end of a long pedicel, c. 25 mm to 50 mm long, c. 5 mm to 8 mm wide, and has a long curving beak (style) which reaches 10 mm or more in length.

Lathyrus inconspicuus L. has smaller leaves than *L. gorgonei* and the leaflet pairs are narrower. Flowers are solitary and have a blue corolla. The pods stand erect, on very short pedicels, and are comparatively long and narrow (c. 30 mm to 60 mm long and c. 3 mm to 5 mm wide).

Taxa in the genus *Medicago* L. were identified on the basis of their distinctive spirally coiled pods.

Medicago orbicularis (L.) Bart. has a broad disc-shaped pod (10 mm to 15 mm in diameter) which has a thin wing-like margin. The pod coils between two to five times and each coil can hold up to 6 seeds.

Medicago rotata Boiss. has a cylindrical pod consisting of three to five coils of equal width (c.10 mm in diameter) and two smaller outer ones. Along the margin of each coil and at right angles to the coil surface, are short spines.

The pod of *Medicago scutellata* (L.) Mill. has five to eight inwardly curving coils which gradually diminish in width towards the base and apex (i.e. it is barrel-shaped). The margin of each coil is spineless.

Medicago turbinata (L.) All. has, like *M. scutellata*, barrel-shaped pods, however, the coils are flat rather than curved and the whole pod is somewhat smaller. In the mature pods, the coils (usually four to nine) become very compact and hard. The spines are very short, curve inwards towards the suture and are strongly appressed to the coil margin.

Onobrychis squarrosa Viv. is again distinguished from other members of its genus by its pods. These are subglobular, have two rows of pits at the base of each lateral side, and are topped with three crests. Of the three crests, the lateral ones have simple spines but the main crest has three or four flattened prickles which have denticulate margins.

Ononis antiquorum L. var. leiosperma (Boiss.) Post is a shrubby perennial with rather slender erect stems and spinous branches. The flowers are solitary, axillary, and have a pink corolla. The calyx measures approximately 5 mm to 8 mm and is longer than both the pedicel and the pod.

Ononis natrix L. is an evergreen or dwarf shrub which is much bushier and more branched than *O. antiquorum*. It is also covered throughout with a mixed indumentum of long and short glandular hairs. The flowers are in terminal, leafy racemes on long pedicels. The corolla is yellow but the upper petal (standard) is often striped with red. The pod is two to three times as long as the calyx.

Scorpiurus muricatus L. has long (30 mm to 80 mm) lanceolate-spathulate leaves. The pod is very distinctive: it is normally loosely coiled into a ring and heavily constricted between seeds. The whole pod is also longitudinally ridged and the ridges are covered with simple (usually purple tinged) prickles.

Tetragonolobus palaestinus Boiss. et Bl. resembles *Lotus* L. in many aspects. It has, however, single flowers (commonly) which have a red or purple corolla and the pod is long (up to 70 mm) with four wide and wavy wings.

Trifolium dasyurum C. Presl (Syn. *T. formosum* D'Urv.) has spike like heads (20 mm to 60 mm in length). The calyx is tube has 10 nerves and the calyx teeth are approximately twice as long as the tube, equal in length, and tend to spread in maturity. The purple corolla is just shorter, or as long as, the calyx. It can be easily distinguished from *Trifolium purpureum* Loisel. by its generally smaller form and shorter corolla.

Trifolium campestre Schreber has cone-like fruiting heads. This effect is given by the curving upper petals (standard) of the corollas which overlap like the tiles on a roof. The corolla is yellow and fades to a pale brown when the plant is in fruit.

In *Trifolium clusii* Godr. et Gren. (Syn. *T. resupinatum* L.), the white fruiting calyces form a very distinctive compact globular head. Between the inflated calyces are the withered and dried remnant corollas.

The leaflets of *Trifolium stellatum* L. are obvate and markedly dentate in their upper part. The calyx is campanulate and the calyx teeth spread into a 'star-shape' when the plant is in fruit.

Trigonella caelesyriaca Boiss. has a subumbellate inflorescence consisting of 5 to 12 flowers. In the field, it was most frequently found in pod. The pods are highly distinctive - 30 mm to 45 mm long, 2 mm to 5 mm wide, flattened, glabrous, and marked with longitudinal nerves.

Vicia peregrina L. usually has solitary flowers. The calyx is approximately the same length as the pedicel and the purple or blue corolla is about double the length of the calyx. The pod is up to 50 mm long and 12 mm wide, compressed, and glabrous when fully mature. The seeds are brown mottled with black.

Vicia sativa L. subsp. *angustifolia* (L.) Aschers et Graebn. (Syn. *V. sativa* L. subsp. *nigra* (L.) Ehrh.) is the 'wild' relative of the cultivar *Vicia sativa* L. subsp. *sativa*. It is smaller than its very close relative and, indeed, this is one of the main characteristics used in its separation from the cultivar. In addition, the mature pods tend to be less contracted between seeds than in the cultivated form. The seeds are yellow or slightly mottled. *Vicia sativa* subsp. *angustifolia* has almost sessile flowers and a relatively narrower pod than *V. peregrina.*

4.2.4.17 Linaceae

Linum pubescens Banks et Sol. have erect stems which branch out dichotomously. The stems are white and sparingly patulous hairy. The plant has showy flowers with large (20 mm to 30 mm) pink petals. The sepals are two to three times as long as the round capsule.

4.2.4.18 Malvaceae

The perennial *Alcea acaulis* (Cav.) Alef. has a woody base and is almost stemless. The leaves are roughly kidney-shaped and the upper leaves are shallowly lobed. The flowers are solitary, axillary, and usually crowded at the base of the plant. The petals are usually pink and the fruit is large and contains numerous mericarps. The backs of the mericarps are furrowed and prominently wrinkled.

4.2.4.19 Papaveraceae

Members of the genus *Papaver* L. were usually identified by their capsules.

Papaver argemone L. has a very distinct capsule: it is oblong, club-shaped to oblong cylindrical, and sparsely covered with bristles. The stigmatic disc is usually narrower than the capsule.

The lower leaves of *Papaver rhoeas* L. are petiolate, pinnately lobed with oblong-lanceolate segments. The upper leaves are mostly sessile and also deeply pinnately lobed although the segments are linear-lanceolate (i.e. much narrower than in the lower leaves). The capsule is mostly broadly ovoid to cylindrical and the stigmatic disc is generally flat and at least as broad in diameter as the capsule. The stigmatic disc has between six to sixteen stigmatic rays and the free lobes of the disc tend to broaden and overlap towards their tip.

4.2.4.20 Plantaginaceae

Plantago afra L. has an inflorescence which is a either an ovoid or cylindrical spike. The seeds are held in ellipsoidal capsules which dehisce transversely. The seeds are glossy brown, narrowly elliptic (c. 2 mm to 3 mm long), and approximately three times as long as they are broad.

4.2.4.21 Polygonaceae

Polygonum patulum M.B. (Syn. *P. patulum* Bieb., *P. bellardii* All.) is an erect slender herb with linear-lanceolate leaves. The flowers are scattered along the stem but become closer together towards the apex. The perianth is tinged with pink and is the same length as the pedicel (c. 2 mm to 3 mm long). The achenes are trigonous and dark-brown.

Rumex pulcher L. has panicles which are composed of elongated spreading branches. The whorls are many flowered and mostly subtended by leaves. The three valves of the fruit are leathery, broadly triangular, and have two to three tiny spines on either side of the base. Each of the valves has a well developed wart at its base which is either wrinkled or covered in tiny protuberances.

4.2.4.22 Primulaceae

The leaves of *Anagallis arvensis* L. var. caerulea (L.) Gouan are in pairs and sit on opposite sides of each node. The solitary flowers are situated in the leaf axils and sit on long slender pedicels which are considerably longer than the subtending leaf. The corolla is blue, c.10 mm in diameter and as long as the calyx. The capsule dehisces transversely releasing numerous tiny seeds.

4.2.4.23 Ranunculaceae

Ranunculus arvensis L. has very distinctive achenes which are laterally compressed and broadly ovate (c. 5 mm to 8 mm across including the beak). The margin is prominently nerved and fringed at both edges with stiff prickles which are longer than those of the disc. There are four to eight such achenes per head.

4.2.4.24 Resedaceae

Reseda lutea L. has leaves which are divided into two or three linear, oblanceolate or spathulate lobes and have rough margins. Its flowers are in spike-like racemes and the calyces and corollas are divided into six to eight parts. The capsule is c. 6 mm to 18 mm long, usually cylindrical, and three-toothed. The seeds are normally smooth.

4.2.4.25 Rubiaceae

The leaves of *Asperula arvensis* L. are in whorls and the inflorescence sits at the top of the stem. The involucral leaves are oblong and either equal in length or extend slightly beyond the blue flowers. The mericarps are globose (c. 2.5 mm in diameter), brown and almost smooth. The area of the inflorescence is somewhat hairy, unlike the stem and leaves which are glabrous.

Galium tricornutum L. also has leaves in whorls and the cymes are axillary, rarely exceeding the leaves in length. The mericarps are globose to ellipsoidal (4 mm to 5 mm in diameter) and densely tuberculate.

4.2.4.26 Santalaceae

Thesium humile Vahl is an erect light yellowish green herb with several erect stems or branches which shoot off from its base. It has many linear-filiform leaves and nutlets. The nutlets are up to 6 mm in length and prominently wrinkled between their longitudinal ribs.

4.2.4.27 Scrophulariaceae

Linaria chalepensis (L.) Mill. has slender glabrous stems which end in a loose raceme. The pedicels of the flowers are much shorter than their calyces. The calyx lobes are spreading, pointed, and about as long as the corolla. The corolla is white with a slender spur, approximately 1.5 times as long as the corolla. The capsule is ovate, shorter than the calyx, and contains angled and wrinkled seeds.

Veronica syriaca Roem. & Schult. is a small annual with stems that branch out from the base of the plant. The corolla is predominantly blue but has a white lower lobe and is c. 10 mm in diameter. The capsule is two-lobed with a protruding style that is approximately the same length as the capsule lobes.

4.2.4.28 Umbelliferae

The stems of *Ainsworthia trachycarpa* Boiss. (Syn. *Tordylium trachycarpum* (Boiss.) al-Eisawi) are covered with stiff short hairs. The upper cauline leaves are either simple or have small lateral lobes around the margins. The umbellule has between 15 to 25 flowers. The petals of the peripheral flowers are large and radiate outwards. The mericarps are broadly elliptical, strongly compressed and have creamy thickened margins.

Astoma sesilifolium DC. is a glabrous perennial with tuberous roots. It has distinctive flowering and fruiting parts. The flowers are tiny with 5 minute white petals. The fruits are also small, c. 1.5 mm by 2 mm. The mericarps are black, almost globular, have a concave inner face, and five white ribs on the outer face.

Bifora testiculata (L.) Spreng. ex Schult. is easily recognised by its heavy foetid smell. The umbels are usually two or three rayed and the umbellules are two to six flowered (the petals are white). The fruit is separated into two mericarps which have wrinkled surfaces, rounded bases and pointed apices.

Bunium elegans (Fenzl) Freyn (Syn. *B. pauciflorum* DC. var. *pauciflorum*) is a glabrous perennial with fine erect branches. The umbel is long-peduncled and the rays are almost equal in length, c. 20 to 50 mm. The white petals are 2 mm long and marked with a dark nerve. The fruit is oblong (c. 5 mm long), glabrous, and has long styles (c. 2 to 3 mm long).

Bupleurum lancifolium Hornem. var. *lancifolium* (Syn. *B. subovatum* Link ex Spr. and incorrectly called *B. intermedium* Poiret in the Flora of Turkey (S. Snogerup pers. comm.)) has very distinctive bracteoles at the base of the umbellules: they are ovate with a rounded base and pointed tip. The umbellules contain 15 to 25 flowers (the petals are yellow). The fruits do not separate into mericarps. The fruits are large (c. 4 mm to 5 mm long) and have a tuberculate surface patterning and prominent vertical ridges. The fruits are larger than those of *B. lancifolium* var. *heterophyllum* (Syn. *B. lancifolium* Hornem.). All the specimens collected in the field were identified as *B. lancifolium* var. *lancifolium*.

Bupleurum nodiflorum Sm. has very distinctive linear-lanceolate bracteoles which are translucent, prominently three-nerved, and cover the buds and the fruiting parts. The fruit itself is small (c. 1.7 mm to 2 mm long) and the mericarps are prominently ribbed.

Daucus bicolor Sm. (Syn. *D. broteri* var. *bicolor* (Sibth. & Sm.) Boiss.) has bristly stems and the flowering umbel is c. 15 mm to 40 mm in diameter. The bracteoles are usually longer than the flowering umbellule. The petals are white but the sterile central flowers are frequently purple. The fruit is ellipsoidal with hair-like spines on the primary ridges and longer stouter spines, whose bases join together to form 'wings', on the secondary ridges.

Daucus carota L. is a very tall plant up to 2 m high. The flowering umbel is between 50 mm and 250 mm in diameter. The white outer petals of the peripheral flowers radiate outwards and the sterile central flowers are usually purple. The umbel is very often heavily inflexed in fruit.

Eryngium creticum Lam. is tinged all over with blue. The stems are prominently ribbed and the branches spread out at or below the middle of the plant. The inflorescence is forked repeatedly and composed of many heads - each of which consists of more than fifteen flowers. The bracts are longer than the heads and sparsely spiny near their bases.

Falcaria vulgaris Bernh. has very distinctive leaves. The lower leaves, for example, are divided into three long linear segments and have serrulate margins. The umbels are long peduncled with 5 to 15 rays. The fruits are oblong-linear, 3 mm to 5 mm in length, and shorter than their subtending pedicels.

Lagoecia cuminoides L. is easily distinguished by its globose fruiting heads, c. 9 mm to 18 mm in diameter. There are many rays in each umbel but each umbellule is only one-flowered. The bracts, bracteoles and sepals are usually pectinate (having lobes that resemble the teeth of a comb). The single mericarp is loosely covered by the bracteole and crowned by the sepals.

Ridolfia segetum (Guss.) Moris smells similar to fennel. It was usually found either in its vegetative or flowering state. Its leaves are deeply divided with fine thread-like lobes. The umbels have long slender rays and there are no bracts or bracteoles. The umbellules are many flowered and the flowers have yellow petals.

Scandix pecten-veneris L. has very long fruits, up to 70 mm in length. The beak of the fruit is approximately three to four times as long as the seed bearing portion, is dorsally compressed, and has short bristles along the margins. The mericarps are marked with brown-green ridges.

The umbels of *Torilis arvensis* (Huds.) Link are all situated at the end of the stems and have between two to twelve rays. The fruits are between 3.5 mm to 6 mm long and the whole surface is covered with horizontal spreading spines. *T. leptophylla* (L.) Reich. has slightly larger fruits than *T. arvensis* and the umbels are positioned along the stems, often in opposition to the leaves.

Turgenia latifolia (L.) Hoffm. was most often recorded when the plants were in fruit. The fruits themselves are comparatively large (c. 10 mm to 12 mm long), ovoid and taper towards their apex. The mericarps are flattened on their inner face and the outer face has five primary and four secondary ridges which bear single or double rows of spines. The spines of the inner seven ridges have spiny hooks at their apex.

4.2.4.29 Rare Taxa

Taxa found in two fields or less are listed in Appendix 4.2. Not all the taxa could be identified to species level, either because they were insufficiently well developed or because they had lost their main identifying criteria (i.e. flowers or fruits). The rare taxa were identified in such detail because the fruits and seeds were to be added to a reference collection.

4.2.5 Soil Analyses

A soil sample was taken from every field included in the ecological analysis. The soil was sampled from a position along the transect at a depth of 100 mm below the soil surface. The samples were tested for organic content, pH and magnetic susceptibility.

4.2.5.1 Organic Content

Organic content was assessed by titration with potassium dichromate. This method was chosen because the soils of the study area are very poor in organic matter (typically c.

1%) and it is more sensitive than, for example, measurement by loss-on-ignition. Loss-on-ignition is also not recommended for soils with a high calcium carbonate content (Gale & Hoare 1991, 262) and the soils of northern Jordan tend to be very rich in calcium carbonate. The procedure used was derived from the Walkley and Black method (cf. Walkley 1947). It is based on the oxidation of organic carbon (C) with potassium dichromate ($K_2Cr_2O_7$). The procedure followed is described below (laboratory procedure used at Yarmouk University, Jordan).

4.2.5.1.1 Titration of Organic Matter by Potassium Dichromate

0.1-0.3 g of ground soil was weighed and placed in a conical flask. To this was added 10 ml of potassium dichromate and 20 ml of sulphuric acid (H_2SO_4). This was shaken by hand for a minute and then heated in a water bath for 15 minutes. This completed the oxidation.

Equation for the oxidation:

$$2K_2Cr_2O_7 + 3C + 8H_2SO_4 \rightarrow 2K_2SO_4 + 2Cr_2(SO_4)_3 + 3CO_2 + 8H_2O$$

After the oxidation, 200 ml of distilled water, 10 ml phosphoric acid and 1 ml of di-phenylamine indicator was added. The excess dichromate was then titrated by adding ferrous sulphate ($FeSO_4.7H_20$) from a pipette until the solution flashed from purple to green. Organic matter was then calculated using the formula:

$$\% \text{ Organic Matter} = \frac{(V1-V2) \times 3 \times 100}{W \times 1000}$$

Where V1 = Volume of potassium dichromate (ml)
V2 = Volume of ferrous sulphate (ml)
W = Weight of the sample (gm)

This procedure was repeated three times for each soil sample and a mean obtained although any result diverging from the other two by more than 5% was eliminated from the calculation.

4.2.5.2 pH

The pH of the samples was measured with an electronic pH meter. The procedure used followed Briggs (1977, 110-111). 10 g of air-dried soil was placed in suspension with 25 ml of distilled water and allowed to stand for c. 30 minutes. The electrode was placed in the soil suspension and readings taken at least three separate times to ensure that the most consistent reading was recorded. In addition, the test was conducted three times for each field, i.e. three sub-samples of each soil sample were tested, and a mean calculated although any result diverging from the other two by more than 5% was eliminated from the calculation.

4.2.5.3 Magnetic Susceptibility

The soils of the study area are rich in the clay mineral montmorillonite. This mineral has a small particle size and a great affinity for water (Fitzpatrick 1983, 14). Soils containing montmorillonite tend to crack deeply during the summer months. Its strong affinity for water means that soil particle size is difficult to assess by traditional means because the particles cannot be disaggregated easily (S. O'Hara pers. comm.). The measurement of mass specific magnetic susceptibility, therefore, was used as an approximation for particle size. It is a method usually used to determine whether a soil is weathered or not and to what degree. According to Gale and Hoare, there is often a close relationship between particle size distribution of regolith material (sediments, soils and weathering products) and magnetic susceptibility (Gale & Hoare 1991, 205). Magnetic susceptibility also has the advantage of being a comparatively quick and easy test which is also non-destructive.

The experiments were performed using a Bartington magnetic susceptibility meter (model MS2B) with a laboratory sensor. The soil samples were air dried and stones larger than 4mm removed. A portion of the soil was then placed in a 10 cc sample pot and weighed to an accuracy of 0.001g. Each pot was placed in the laboratory sensor and the magnetic susceptibility measured at low frequency. To calculate mass specific magnetic susceptibility ($10^{-8}m^3kg^{-1}$) the following formula was used:

$$Xlf = \frac{xlf}{((M2-M1) / 0.01)}$$

Where Xlf is the initial reversible low frequency mass susceptibility (units $10^{-8}m^3kg^{-1}$)
xlf is the susceptibility of the sample pot, lid and contained sample
M2 is the mass of the sample pot, lid and sample (gm)
M1 is the mass of the sample pot and lid (gm)

The experiment was repeated three times for each soil sample and a mean obtained although any result diverging from the other two by more than 5% was eliminated from the calculation.

4.3 Data Preparation and Manipulation

The botanical data and the 'external' data were prepared for use with the packages SPSS (SPSS Inc. 1990) and CANOCO (ter Braak 1987-1992) (see section 4.4). To do this, a number of preparatory stages were undertaken.

4.3.1 Input of the Botanical Data

The botanical data were prepared in the following way. Each taxon and each group of undifferentiated taxa - for example, *Lolium* spp. - was allocated an individual taxon number. Abbreviations of the taxon names were also allocated and, for taxa identified to species, based on the first four letters of the genus name and the first three letters of the specific name so that, for example, *Sinapis arvensis* becomes SINAARV (the variety or subspecies identification is not included in the abbreviation). A full list of the taxa and taxa abbreviations is given in Appendix 4.1.

As well as recording the presence of a taxon within a quadrat, its stage of development, from vegetative to fruiting state, had also been noted. These developmental stages were coded on an eight point scale (M. Charles pers. comm.) (Table 4.2). Developmental stage 1 corresponds to a taxon which could not be confidently identified to species level and was found in its vegetative state. The vegetative state is, almost always, the most difficult developmental stage at which to identify a plant accurately. Developmental stage 1, therefore, represents the least confident level of identification. Developmental Stage 8, however, corresponds to a taxon which was confidently identified and was flowering and fruiting. A plant which is both fruiting and flowering possesses the two main features used to identify most taxa. This developmental stage, therefore, represents the most confident level of identification. Stages 2 to 7 (Table 4.2) represent more or less progressively secure levels of identification between these two extremes.

The data were entered into the computer in the following way: each line began with the field and quadrat numbers which were then followed by a number of 'couplets' representing the taxa present in each quadrat. The fields were numbered consecutively from 1 to 60 and each of the 10 quadrats within each field was numbered from 0 to 9. Thus the third quadrat from field 54, for example, was coded as 542. The 'couplets' were composed of a taxon number and a developmental stage code. Thus a securely identified specimen of *Sinapis arvensis* (taxon number 109) found in its fruiting and flowering stage translated as the 'couplet' 1098.

4.3.2 Data Manipulation

The botanical data were next converted into Cornell condensed format (ter Braak 1988, 9) for use with the Ordination package CANOCO (ter Braak 1987-92). The data were converted into condensed format in two forms - referred to as 'level 1' and 'level 2' - following original criteria defined by G. Jones. The 'level 1' data set utilises the maximum amount of botanical information collected. It includes taxa which were not fully identified to species level (identifications including the prefix 'cf.') and plants which may have been identified at a stage of development, such as the vegetative state, where many of the key characteristics used to securely identify a plant were missing. It also includes taxa which were combined due to difficulties distinguishing them to species level or where there may have been inaccuracies in the original field identifications. The genera grouped in this way were *Anthemis* spp., *Lolium* spp., and *Euphorbia* spp.

After examination of the collected specimens, it was decided that there may have been some confusion between *Anthemis pseudocotula* and *A. palestina* (and possibly including *A. hebronica*) in the field and especially during the first year of field sampling when these taxa were observed primarily in the flowering or early fruiting stages. In the second year of botanical fieldwork, *A. palestina* was recorded more often than *A. psuedocotula.* For the purposes of the 'level 1' analysis, however, all the *Anthemis* species were grouped together. The group *Lolium* spp. was combined for similar reasons and includes the three taxa *Lolium temulentum, L. rigidum* and *L. subulatum*. Subsequent sampling in the second year suggests that the dominant species was *L. temulentum* although, particularly in the hills, *L. rigidum* also had a significant presence. *Euphorbia* spp. combines *Euphorbia reuteriana* and *E. falcata.* but excludes *E. aleppica*, which is easily distinguishable from the other species. *Euphorbia reuteriana* and *E. falcata* were difficult to distinguish in the field because most of the plants were badly damaged and had lost their fruits and seeds. According to Flora Palaestina, *E. falcata* is the more common of the two species.

'Level 2' uses only the taxa which were securely identified to species. It, therefore, excludes all 'cf.' identifications and only those occurrences of the grouped taxa where specimens had been taken which could be accurately identified. As a consequence, many observations of *Anthemis* spp., *Lolium* spp. and *Euphorbia* spp. are omitted from this data set. It also excludes taxa which were observed at a stage of development where the identification is less secure. For each taxon, therefore, the ease of identification in the vegetative, flowering and fruiting stages was assessed (see Appendix 4.3) and the results of this assessment were applied to the collected data.

The original data was manipulated into the above two data sets ('level 1' and 'level 2') and transformed into Cornell condensed format using a sequence of FORTRAN and SPSS programs (devised by T. Dargie and G. Jones) on the mainframe IBM and Prime computers at Sheffield University. In the final data sets, the taxa found in each field are listed in numerical order along with the number of quadrats (out of 10) in which they appear.

4.3.3 Inputting the External Variables

The external variables were entered into the computer in Cornell condensed format and converted into full format via the program CEDIT (part of the CANOCO package) for use with SPSS, CANOCO and CANODRAW (Smilauer 1992). First, however, the external variables were coded.

The external variables include nominal, ordinal and quantity variables (Rowntree 1981, 28-34). Nominal variables are variables which can only be classified, or categorised, by their name. For example, from the current analysis, vegetation zone is a nominal variable and has categories such as 'degraded deciduous forest' and 'evergreen forest'. Ordinal variables are also categorised by name but the categories can be ranked or arranged in order. For example, the position of a field on a slope is arranged in this study into categories from the upper third of the slope down to the basin bottom. Finally, there are quantity variables which have true numerical values. For example, altitude and the number of children in a household are quantity variables. (The number of children is a discrete measurement, i.e it is not possible to have, say, 1.5 children, whereas altitude is a continuous measurement, i.e. it is possible to imagine any division.)

The variables are listed in Tables 4.1a-c and described below. Each quantity variable was attributed an individual code but each nominal and ordinal variable category, rather than the variable itself, was attributed a code (ter Braak 1988, 11).

4.3.3.1 Inputting the 'Cultural' Variables - Crop Management Practices

The first, and primary, crop management variable being examined for its effect on weed composition is rotation regime. Six rotation regimes are included in the analysis. Most of the fields were cultivated under either a two or three course rotation regime: these are cereal-legume, cereal-fallow (with and without summer crops), and cereal-legume-fallow (or cereal-fallow-legume). The 'cereal' (i.e. the crop that was sampled for weeds) was always wheat. Five fields, however, were included whose cropping history did not fall into these standard patterns. These include three fields which had previously been left uncultivated (i.e. weedy fallow) for five years, one field which had been previously cultivated with wheat, and one field which had been cultivated with summer crops for ten years prior to its planting with wheat. The second primary crop management variable is the previous year's crop and includes fields which had been either bare fallowed or cultivated with one of the following - a cereal, legume, or summer crop. Other nominal variables are: the tillage power used, the sowing time, how the field was fertilised, and whether the field was weeded. Finally, sowing rate was calculated by dividing the amount of seed farmers said they had sown by the size of the field or plot. The crop management 'cultural' variables are summarised and listed in Table 4.1a. They are used in the multivariate analysis (see 4.4).

4.3.3.2 Inputting the 'Cultural' Variables - Farming Background

The following variables are included as background factors affecting crop management (Table 4.1b). These background variables are used in the decision-making analysis (chapter 6). First, there are the farmers' personal details starting with their age and occupation. Value judgements were made concerning the experience and knowledge of people cultivating the land. The most experienced full-time farmers who had learnt their skills locally were placed under the occupation category of fellah. Most of these people were the very oldest farmers, had been farming all their lives and called themselves fellaheen. After this, there were farmers who had grown-up working the land but had spent some time away, usually in the army, before returning to farming (coded as 'ex-army'). Finally, there were people for whom agriculture was, and had always been, a secondary occupation. These people were divided into two categories: people who worked in a skilled occupation ('educated') and those who laboured manually ('labourer'). In general, those who worked in a skilled occupation spent less time on the land than 'labourers', however, this observation was not systematically documented. Finally, the number of children is included in the farmer's personal details.

The tenural relationship is also an important variable included as part of the farming background. Land was either owned outright by the farmer, by or with a relative, or rented. Rented land was either rented for a share of the crop or for cash. The amount of land held in wheat and other crops was also recorded.

Finally, details about the farmers' animals were summarised for inclusion as 'cultural' variables. Types and number of livestock held were converted into a quantitative form using FAO livestock units (Table 4.3). The presence of equine animals, i.e. donkeys or horses, were also included as a nominal variable.

As stated above, the 'background farming' variables are used as the basis for the decision-making analysis (chapter 6). The cross-tabulations and associated statistics used in this analysis were calculated and compiled using SPSS.

4.3.3.3 Inputting the 'Environmental' Variables

The following 'environmental' variables were included as factors which affect both the choice of rotation regime and weed composition directly: location of the fields in terms of the hills and plains, vegetation zone, altitude, and the situation of the field in relation to slope, degree of slope and aspect. The soil properties - stoniness, organic content, pH and magnetic susceptibility - are also included. The height and the percentage cover of the crop are also included as 'environmental' variables but the status of these variables is somewhat ambiguous because both can be cause and effect. Crop height and cover are both influenced by environmental factors and crop management practices and can in turn affect the weed flora because a crop competes with weeds for light, moisture and nutrients. The environmental variables are shown in Table 4.1c. The environmental variables and the crop management variables are the 'external variables' used in the multivariate analysis.

4.4 Multivariate Analysis

The botanical data and external variables were subjected to multivariate analysis using the ordination technique, correspondence analysis (CA) (Gauch 1982; Jongman *et al.* 1987; Jones 1991). As with other ordination techniques, this technique produces an ordination diagram arranging sites (in this case, fields) along axes on the basis of species (in this case, weed species) composition (Jones *et al.* in press). Furthermore, correspondence analysis maximises the difference between samples based on species composition (Jongman *et al.* 1987, 138). By reducing the data to diagrammatic form, large amounts of data can be more easily assimilated by the human mind (Van der Veen 1992, 111). In an ordination diagram, the position of each site relative to all other sites and of each species relative to all other species is displayed. Points (sites or species) which are close together are alike and indicate a similar response to a gradient (some extrinsic factor - in this case, perhaps the external variables recorded) whereas the opposite is true for points which are far apart. The direction of a point away from the origin indicates its type of divergence whereas the distance of a point away from the origin indicates its degree of divergence. The distance between sites is significant as is the distance between species. The distance between sites and species, however, is not significant although the direction is (Lange 1990, 43).

Correspondence analysis is a 'pattern-searching' (or indirect) ordination technique which is used to identify major axes of variation in species data (Jones 1991, 70). The first axis generated by the technique represents the gradient which best accounts for the variability in the species data (Jongman *et al.* 1987, 95). When this variation is removed, the second axis accounts for most of the rest of the variation and this process continues although CANOCO stops the analysis at the fourth axis. These axes have to be interpreted in the light of what is known about 'environment', or background, of the sites (Jongman *et al.* 1987, 95). Canonical correspondence analysis (CCA), is a 'middle-path' between 'pattern-searching' (indirect) and 'problem-orientated' (direct) analyses as it is used to detect patterns in compositional variation that can best be explained by known gradients (in this case, the external variables) (Jones 1991, 70), i.e. it permits the external variables to be included in the analysis of the species.

The program used in the analysis of the data was CANOCO (ter Braak 1987-92) originally designed for the analysis of vegetation survey data. CANOCO is an extension of DECORANA (for detrended CA) (Hill 1979) and allows for the analysis of the relationship between species and external variables in two alternate ways. First, the external variables can be superimposed on the ordination diagram produced by the correspondence analysis and the relationship observed. Alternatively, canonical correspondence analysis can be used; this is a technique that selects the linear combination of external variables that gives the maximum separation of samples on the basis of species composition (CCA can therefore be considered a restricted CA)(Jongman et al. 1987, 138). Using these two techniques, the way species composition responds to a particular external variable can be assessed. Partial canonical correspondence analyses (PCCA) can also be undertaken in CANOCO. In a partial analysis, the effects of particular external co-variables (i.e. variables which are not under investigation) are eliminated and the residual variation is related to the variables of interest (ter Braak 1988, 2).

The CANOCO program includes a Monte Carlo permutation test (ter Braak 1988, 2) in which samples are randomly assigned to values of the external variables and the ordination repeated. The analysis is repeated 99 times with different random permutations. If the eigenvalues of the test data are greater than for any of the random permutations then the result is significant at the 0.01 level. If 95 of the random permutation have values smaller than the eigenvalues of the test data and four have values that are greater, then the result is significant at the 0.05 level. In this study, the test was performed on both the first eigenvalue (the first axis) and the sum of all the eigenvalues.

The detrending methods offered in the CANOCO package were tested but *because, first,* no profound differences were detected between the simple and detrended ordination diagrams and secondly, there were no traces of the 'arch effect' (ter Braak 1985, 865-866; 1988, 17), detrended correspondence analysis was not used. The program used for plotting the results was CANODRAW (Smilauer 1992).

In community ecology, it is usual to omit rare taxa from a data matrix prior to multivariate analysis (Gauch 1982, 213-4). It is typical to omit taxa occurring in less than 5% or 10% of samples (Dagnelie 1973, 231; Gauch 1982, 213-4; Lange 1990, 76). In this study, analyses performed using 100% of the taxa had an extreme effect on the ordination diagrams. This is because, due to the process of reciprocal averaging, rare taxa (and samples containing those taxa) are placed at the extreme ends of ordination axes (Gauch 1982, 152). Omitting taxa occurring in less than 5% of the fields (taxa occurring in less than three fields) significantly improved the clarity of the ordination diagrams. Omitting taxa occurring in less than 10% of the fields (taxa occurring in less than six fields) did not appear to increase the clarity of the ordination diagrams and furthermore, some of the differentiation between fields seemed to be lost. Therefore, taxa occurring in at least 5% of the fields were used in the analyses. This reduced the number of taxa included in the 'level 1' analyses to 108 (from 162 coded taxa) and 109 (from 166 coded taxa) in the 'level 2' analyses.

4.5 Summary

In this chapter, the ethnographic, ecological and statistical methods used in this study have been outlined. The way the ecological data and the information derived from interviews with farmers were summarised for exploration using statistical techniques has also been detailed. In chapter 6, the information collected in the interviews (the farming background variables) and observations of local farming practices will be used to examine the reasons why people manage the land in the way they do. Following on from this, in chapter 7, the effects of different crop management practices on weed composition will be explored. Next, however, the contemporary farming practices of the study area will be described in an attempt to define the local 'decision-making environment' (chapter 5).

Chapter 5 The Decision-Making Environment

The aim of this chapter is to set out the nature of farming in northern Jordan: the crops cultivated, farming equipment, animals held, and the year-to-year cycle of events. The greater part of this chapter concentrates on the agricultural year which begins with the onset of winter rains - signalling the time to plant wheat - and culminates in the long dry summer months when crops are harvested. The main arable crops, however, are discussed first. Wheat is the primary and most prestigious arable crop. Other major winter crops are barley and legumes such as lentil and bitter vetch. A wide range of summer fruits and vegetables is also cultivated. Significant tree crops, notably the olive, are also described.

The major field implements are the ard (or scratch-plough) and tractor-drawn plough. Tillage is a major component of traditional crop management - indeed farmers formerly derived status from the number of working oxen and ards they held - and, for example, tillage is the main factor which contributes to the success of bare fallow (see 3.1.4). For the farmers that are the focus of this study, arable crops are usually hand-harvested although crop-processing is generally carried out by machine.

Animal-holding is integrated into the arable economy - animals provide milk, meat and manure as well as embodying wealth - but to do this they require fodder. Animals held by local farmers will be discussed as well as traditional sources of fodder. Throughout the discussion comments will be made on the changes in farming practice that have occurred during this century and are preserved in the memory of the older farmers. The local units of measurement are also introduced as it is upon these units that farmers calculate their needs and assess their losses.

5.1 Plant Resources - Arable Crops under Cultivation

5.1.1 Winter and Summer Crops

Arable crops are locally referred to as either 'winter' (shatawī) or 'summer' (ṣaifī) crops. This refers to whether they are planted during the rainy period or immediately after it. Wheat, barley, lentil and bitter vetch are the main winter crops. Collectively, legume crops are referred to as qatāna. Occasionally, in the hills, bitter vetch and lentil can be planted at the end of the rainy period and are classified as summer crops. Under normal circumstances, however, they are classified as winter crops. Onions also can be planted in either the winter or spring seasons. The main winter and summer crops cultivated in northern Jordan are listed in Table 5.1.

5.1.2 Winter Crops

5.1.2.1 Winter Cereals

Wheat (qamh) and barley (sha'ir) are the dominant winter crops. From the earliest years of the Hashemite Kingdom, schemes were initiated to promote high yielding hybrid wheat varieties (for example, Salim 1961). Today, almost all the wheat under cultivation is a hybrid variety of *Triticum durum* L. (durum wheat) which is the species of wheat preferred for the traditional flat bread of the area. *Triticum durum* is also notable for its suitability to make other staples such as burghul (Williams, El-Haramein & Adleh 1984, 28) as well as its generally perceived hardiness to the environment. The most popular durum variety is 'Hourani' (or 'Hourani Nawawi'), a hybrid derived from the Hourani plains of Syria (el-Hurani 1988, 41). A variety locally known as 'F8' is also cultivated (originally brought from Akka Agricultural Experimental Station in 1935 (el-Hurani 1988, 41)) and farmers also occasionally refer to 'white' or 'yellow' wheat. The *Hourani* and 'F8' varieties were very strongly represented (55.9% and 26.2% respectively) in zones III and IV (the area receiving over 300 mm annual rainfall) of the *Wheat Baseline Data Survey* (el-Hurani 1988, 42). In the Irbid plains survey of three villages, Karablieh and Salem recorded that 74% of seed was 'Hourani', 16.8% 'F8' and only 6% local (Karablieh & Salem 1990, 22). The wheat used by farmers is most frequently referred to as simply baladi ('local') a fact which probably means that the seed grain was carried over from the previous year's harvest (but probably represents one of the hybrid wheats rather than a land-race). Some farmers also said that they bought their grain from the market in Irbid or from the agricultural co-operative (JCO). In the *Wheat Baseline Data Survey*, across all Jordan, 38.9% of farmers said they carried over seed from the previous year (el-Hurani 1988, 90). The percentage is probably greater for those managing smaller farming units.

Local land-races of 2-row hulled barley are still widely grown although introduced high-yielding 6-row hybrid varieties are also increasing in popularity. Barley is now only used as animal fodder although formerly it was also used as human food. Barley is more tolerant to drought (Arnon 1972b and see Table 3.1) and salinity (Doorenbos & Pruitt 1977, 78) than wheat.

5.1.2.2 Former Local Wheat Types, Seed Grain and Storage

It is evident that a variety of wheat land-races were once grown in the area. Most appear to have been varieties of *Triticum durum*. Various names for the different varieties have been given which normally refer to the colour of the glumes and awns, although people most commonly talked about baladī ('local') wheat (also the name given to wheat which is carried over from the previous harvest - see above). There was white, blonde, red, and black wheat and also a variety called mushmūl. Whiter varieties are usually judged to yield better quality grains but blacker varieties appeared to have tolerated more severe growing conditions, such as steep slopes and shallow soils or insect attack. Some farmers commented that different races (e.g. black and white) could be grown together so that should one fail, the hardier type might survive to produce a crop. There are also black and white types of hulled two-row barley cultivated in the Near East. The white variety is cultivated in the wetter zones of the study region while black barley is cultivated in the driest areas (it is not known in the study area).

In the past, and on the plains in particular, some older farmers commented that the seed grain (bidhār) was carefully selected and that each area guarded their supplies carefully. Other farmers stated, however, that the seed grain was not distinct from the grain which was eaten and had been stored together with it. In general, the seed grain was only coarse-sieved.

5.1.2.3 Winter Legumes

The legume crops lentil ('adas), bitter vetch (kirsinna), common vetch (biqiya), and horse bean (fūl) are winter crops (see Table 5.1). They are an important source of human food and animal fodder. In terms of diet, legumes contain two to three times as much protein as cereals and the proteins they contain are complementary, in terms of the pattern and profile of the amino-acids, to cereal grain protein (Bahl 1990). The higher protein content of legumes is linked to their nitrogen fixing ability, through symbiosis with *Rhizobium* bacteria. This capacity to fix nitrogen is also claimed to improve nitrogen availability for the subsequent cereal crop, particularly if practised on a long-term basis (see 3.2.3).

Lentil is one of the two major food legume crops planted in the rainfed areas of Jordan (Haddad & Snobar 1990, 77). In Mediterranean type environments, lentils are mostly grown in regions of low annual rainfall (sometimes less than 300 mm) (Saxena 1981, 124). Of the grain legume crops cultivated in the study area, they are most resistant to drought (M. J. Jones 1990, 196). The major forage grain legume is bitter vetch (*Vicia ervilia* (L.) Willd.) and both the seeds (in broken form) and straw are given to animals. In recent years, farmers have also started growing common vetch (*Vicia sativa* L. subsp. *sativa*) as a fodder crop. The straw from all the legume crops is an important source of fodder and is locally called 'red straw' ('white straw' is cereal derived).

In recent years there has been a great deal of interest in improving lentil varieties (e.g. Haddad (1983b) and the Legume Improvement Project based at the Ramtha Research

Station) so that they can be harvested by combine (by developing non-shattering pods). This research is still at an early stage and mechanised harvesting incurs heavy grain losses (Haddad 1986 in Karablieh & Salim 1990, 28), so local varieties of lentil, as well as of bitter vetch and horse bean, continue to dominate along with hand-harvesting methods. The cultivation of common vetch appears to be a deliberate introduction (or even re-introduction) although the wild sub-species is indigenous to the region and known to the farmers. Cultivated grasspea, *Lathyrus sativus* L. (jilbāna), is also known to the farmers although very rare. Pinner notes that he encountered grasspea and *Vicia narbonensis* cultivated as crops only in the Circassian (nineteenth century settlers originating from the Caucasus) settlements of Transjordan (Pinner 1930, 51).

The legume crops generally require annual rainfall levels above 350 mm to ensure reliable yields. For Syria, Tully notes that the current limit of legume cultivation is between 300 and 350 mm mean annual rainfall (Tully 1989, 26). Horse bean requires higher levels than chickpea or lentil (Harris, Osman *et al.* 1991, 243) and is primarily grown in the higher altitudes of the study area. Legumes generally have a shorter growing period than cereals: the growing period for lentil is c.170 days compared with c.180-250 days for wheat and barley (Doorenbos & Pruitt 1977; Doorenbos & Kassam 1979). Bitter vetch is known as 'the child of forty days' (ibn arba'īn yaum) because of its short growing period - it is the last winter crop to be sown but the first to be harvested (Pinner 1930, 50; Dalman 1933, 1).

5.1.3 Summer Crops

A wide variety of summer crops is cultivated in the study area (see Table 5.1). They are termed summer crops because they are planted in spring and early summer and, therefore, largely depend upon stored soil moisture during their growing period. They have a shorter growing period than winter crops - typically between 80 and 140 days (Table 5.2).

Sorghum is the only cereal grown in the study area that is classified as a summer crop. 'White' sorghum, *Sorghum vulgare* (dhura baidā'), was once widely cultivated and used as both human (to make a bread called kiradish) and animal food. Today, however, sorghum is only grown in selected patches and is generally the type which is used for making brushes (*Sorghum vulgare* Pers. var. *saccharatum*), locally known as makānis (and also 'yellow' sorghum, dhura safrā'). Sorghum is one of the most water efficient field crops, requiring approximately 60% of the water required by wheat to produce the same weight of dry matter (Tivy 1990, 98).

Chickpea (hummus) is the only 'Old World' legume unambiguously referred to as a summer crop. Chickpea is the second major food legume planted in the rainfed areas of

Jordan (Hadded & Snobar 1990, 77). It requires an annual rainfall of c. 400 mm (Saxena 1987, 209). On the whole, local cultivars continue to be utilised. There has, however, been a considerable amount of research investigating the possibility of planting improved varieties of chickpea as a winter crop due to the increased productivity that would result (Haddad 1983a; Saxena 1987, 214-19). This research is still at an early stage as the problems of susceptibility to frost and *ascochyta* blight have not been totally overcome. Additionally, in trials in Syria, winter-sowing was not always viewed as advantageous by farmers.

Other summer crops range from sesame and tobacco (notoriously 'hard' on the land) to the curcurbits and other beans (mostly deriving from the 'New World'). There appear to be regional differences in the summer crops under cultivation. For example, on the plains, sesame, watermelon and tobacco are generally chosen but other crops include broom sorghum, tomato, cowpea, okra, and sunflower. In the hills, however, tomato and okra appear particularly popular. Typically, most of the farmers included in this study planted a little of many types of summer crop.

5.2 Local Measures

In the study area, there is a well established system of traditional measures and the names of the crop measures are still used, although the equivalents of the measures have been standardised to the metric system. There also appears to have been some conflation of the traditional units of weight and volume. The local names for units of land are no longer commonly used and have been replaced by the dunum, $1000m^2$ (originally an Ottoman measure - see 5.2.2).

5.2.1 Local Measures for Crops

The local names and modern equivalents for wheat measures are given in Table 5.3 overleaf.

The local names refer to two systems: one for weight and the second, for volume. The basic unit of weight is a rutul. Cuinet states that the rutul was equal to 2.56 kg for all Syria as it then existed (Cuinet 1896, 371), but there were variants to this equivalent, for example, in Haifa the rutul was equivalent to 2.88 kg (Pinner 1930, 65). In northern Jordan today, the old Syrian rutul (as opposed to the English rutul) is still said to be approximately 2.5 kg.

The basic unit of volume was a sā'. This was, in fact, the name given to the container used at the threshing floor to measure wheat. There seems to have been variation in the size of these containers from region to region. Indeed, there are occasional reports of individuals carrying containers from village to village to ensure that business was done fairly (for example, Wilson 1906, 213). Farmers in the study area commented that the British introduced a new standardised ṣā' which differed from the Ottoman unit. In the study area, the term mudd (plur. timdād) was and is still frequently used as well as fractions of a mudd, such as rubā'īya mudd (quarter mudd). Cuinet, for all Syria, states the volume of one mudd was 17.6 litres (Cuinet 1896, 372). Abujaber states that for al-Yaduda, south of 'Amman, there were three ṣā' in one mudd although most other accounts state that there were only two ṣā' per mudd (Abujaber 1989, 262).

The relationship between the rutul and volume measures is more complex and, at times, even confusing. Different crops and crop products (such as burghul) had different volume and weight equivalents, as might be expected. Farmers, therefore, usually specify whether they are referring to a ṣā' of wheat or another crop. One farmer in Hakama, still using his own ṣā' measurer, gave the following approximations for the 'old' values:

ṣā' wheat = 4 ruṭul
ṣā' barley = 3 ruṭul
ṣā' sorghum = 3.5 ruṭul
ṣā' burghul = 3.5 ruṭul
ṣā' sesame = 2.75 ruṭul

In the study area today, four rutul per ṣā' of wheat is constantly quoted. Rogan, however, gives the historic value as just two rutul per *sa'a*. (Rogan 1990, xv). This seems to have been broadly true. For example, Elezari-Volcani noted that the 'Galilean' kail was equivalent to 72-75 kg for wheat and the leguminous crops, but to 72 kg sorghum, 50 kg barley and 50 kg of sesame (Elezari-Volcani 1930, 31). Pinner states the same weight for one kail for wheat on the Esdraelon Plain (Pinner 1930, 65). If a kail is 12 ṣā', this makes one ṣā of wheat equal to c. 6 kg (also see Abujaber 1989, 64). In general, therefore, there were formerly two rutul per ṣā'. It seems that the measuring system currently in use in northern Jordan (Table 5.3) is a something of a 'hybrid': it is a combination of old and new measures as well as a conflation between measures of volume and weight. A number of farmers have, indeed, commented that the new mudd (now c. 20 kg) is larger than the former one. It is likely, of course, that in the past different areas, such as northern Jordan and al-Yaduda, equated the relative names differently.

5.2.2 Local Land Units

The rub'a and the qirāṭ are the main old land units referred to by older farmers. The rub'a means 'one quarter' and seems to have been equivalent to one quarter of the largest unit - a fidān (see below). A fidān consisted of 24 qirāṭ. The qirāṭ and fidān were widely used throughout the Levant (see Latron 1936; Firestone 1981, 819; Abujaber 1989, 262). Plains farmers seemed to be more conscious of the old names and could remember the amount of arable land that was held by a village as a whole in terms of rub'a. For example, in el-Huṣn it was said that there were 75 rub'a when 'Mowfid' (which seems to be the name for the British official) came to register the land. It was claimed that there were 28 rub'a' in Hakama and 80 rub'a in et-Turra when 'Mowfid' came. There were also subdivisions of the rub'a - principally the thumna ('one eighth') - which seems to be equivalent to the land that one yoke of oxen could till in a year (i.e. 3 qirāt). A rub'a, therefore, generally required two yokes of oxen (but could occasionally require three). Only rich men were given a whole rub'a during the British land division.

In the hills, on the other hand, land shares were expressed in terms of zalama ('men') (equivalent to dhukūr in Palestine) although people generally knew how many units (qirāt) made up each zalama for a particular village's arable lands. For the villages that made the confederation of Tibna (in the hills), 8 zalama was said to be equivalent to one rub'a, i.e. each zalama was/had 3 qirāt (exactly the same unit as a pair of oxen was normally able to till on the plains). The difference between the way hills and plains shares were locally assigned is embodied in local Ottoman land registers (M. Mundy pers. comm.) and similarly, in the mountainous and plains regions of Palestine (cf. Firestone 1990, 93). The different emphasis on teams of oxen or men is considered to reflect a differing concern with either the units of production (oxen and seed) or the units of consumption (men) (Firestone 1981, 816-19).

The actual areal coverage of each unit seemed to vary from region to region according to the fertility of the soil and the amount that could be tilled in one day (see 5.3.2). For example, in the former instance, in el-Huṣn it was estimated that a qirāt on flat fertile land was equivalent to 20 contemporary dunums whereas on sloping land it was nearer 25 dunums. In Hakama, a village which generally receives more rainfall, a qirāt was estimated to be approximately 14 to 15 contemporary dunum. If a team of oxen cultivated half a rub'a which is equivalent to 3 qirāt, then the amount cultivated per year ranged between 4.2 ha and 7.5 ha. Farmers could also equate units with the amount of seed they needed (also a measure of fertility - see 5.4.2). For example, it was estimated a rub'a in Kufr Saum took a c. 50 timdād of wheat - equivalent today to a seeding rate of c. 6.7 kg/dunum to 11.9 kg/dunum (these are plausible sowing rates - see 5.4.2). Interestingly, Mundy comments that during Ottoman land registration there is a change from recording arable land in terms of seed (interpreted as the local preference) to areal measures (the Ottoman dönüm) (Mundy 1992, 220 & 224). Thus converting a local measure to a unit measurable by outsiders.

The term fidān is interesting. First, it is the term for a pair of oxen and an ard (see 5.3.1). It is also documented as referring to the amount of land that could be tilled in one day (see Bergheim 1894, 192; Cuinet 1896, 373) and finally, as a share or area of land that could be worked by a pair of oxen in one year (see Latron 1936, 14-18;

Firestone 1981, 816). It is evident that in northern Jordan, a fidān was a much larger unit than could be tilled by a single team of oxen - it seems to have required eight teams. In fact, a fidān was indeed said to be equivalent to 8 'hills' zalama - at least for Irbid (M. et-Tell pers. comm.).

The Ottoman unit is the dunum, or dönüm. The dunum is now equivalent to 1000 m^2 but the old dönüm was formerly equivalent to 919.3 m^2 (Latron 1936, 20). Latron also very interestingly comments that in Syria the old dönüm corresponds very closely with a mudd of seed (Latron 1936, 20). Even today, on the plains of the study area, most farmers state that each dunum requires one mudd of seed grain (see 5.4.2). From Mundy's examination of the Ottoman registers, it seems that the officials simply directly converted mudd measures to dönüm (Mundy 1992, 224). Incidentally, the Turkish word dönüm actually refers to tillage - deriving from dön meaning 'a turning' (Firestone 1981, 815). Today, the dunum is the areal unit used by the farmers and the state alike. Traditional units are now no longer used as a result of state standardisation of measurements, land registration and the demise of animal powered, particularly oxen, tillage.

5.3 Tillage Implements, Mechanisation and Efficiency

A pair of oxen and an ard was formerly central to the life of a fellah. Burckhardt, in his travels in the Hauran, noted that an inhabitant of that place 'estimates his wealth by the number of *Fedhans*, or pair of oxen, which he employs in the cultivation of his fields' (Burckhardt 1822, 295). The traditional ard is still used today but is more commonly drawn by donkeys or cows rather than oxen (Plate 5). Tractor drawn ploughs, however, are the dominant tillage implement for most of the study area (particularly the plains) and were, together with the new wheat varieties, the first technological 'innovations' to be taken up.

5.3.1 The 'Traditional' Ard (or scratch-plough)

The traditional tillage implement of northern Jordan is the wooden scratch-plough or ard. It is called a maḥarāth, a noun derived from the verb 'to plough' (ḥaratha), but is also commonly known as an ʿawd ḥarāth, referring to the ard beam, and as a sikka, referring to the share. A pair of oxen and an ard, a fidān, was not only the basic unit of power, or production, but was also seen to symbolise the intimate relationship between the cultivator and the land (see 5.3.3). Oxen (thīrān) are today rarely used but replacement with other animals is still viewed as an inferior substitution, except for a few specific tasks (for example, a single horse for tilling the soil around trees). The traditional ard of northern Jordan (and also northern Palestine) has been described by a number of early commentators and travellers (for example, Dalman 1932, 83-84; Schumacher

1889).

In the village of el-Mazār, a local man (formerly a stone mason, hajjār) was observed making traditional ards from oak wood (Plate 6). The main body of the ard consists of two pieces: a beam and a combined piece for the stilt and sole (Fig. 5.1). The beam is either in one piece for dual animal traction or divided into two pieces with the upper section of the beam split to two parts to allow for a single horse or donkey to be attached (as is shown in Fig. 5.1). Approximately 10 cm before the base of the beam, a hole is carved so that the stilt/sole piece can be slotted into position. The upper end of the stilt/sole is adzed down to a flat piece whilst the lower portion is left with the branch's full circumference but is pointed at its base to receive the share. A third piece of wood, a dog-leg strut, is mortised at both ends into the beam and the stilt/sole, and is secured using a metal tie or band. The handle, which is slotted onto the top of the stilt, is carefully adzed and rasped down to a symmetrical shape bulging in the centre around its mounting hole. Table 5.4 summarises the indigenous names applied to the various components of the ard. The basic structure of the traditional ard broadly conforms to a Type III ard ('with the passing through stilt') as defined by Sach (1968, 12) (for a complete description and comments see Palmer and Russell 1993).

The share consists of a convex triangular iron plate (for similar forms, note Dalman 1932,71-73; and Plates 19, 22), two narrow wings set at mirrored angles and a long tapering tongue at the narrow end. The share is held in position on the sole by the convex shape of the share and an iron strap across the share's lower side. Historically, all pieces of the share were hand wrought iron, although modern examples are of welded steel (as depicted in Plate II). The main action of the traditional ploughshare is that the soil surface is dislodged (rather than inverted as with a modern mouldboard plough) and penetrates to a depth between c.25 and 30 cm (Unger 1984, 93).

In addition to the traditional wooden ard, modern ards constructed completely from iron are also employed in tillage in the study area (Plate 7). These appear to be a comparatively recent phenomenon, with farmers reporting their first appearance some 20 to 30 years ago, and possibly earlier. This ard form is illustrated by Elezari-Volcani (1930, 65). They are principally used in conjunction with a single donkey, and have been observed in use for tillage between summer crops, and in tillage for winter crops sown on very small plots of land.

5.3.2 'Traditional' Tillage Power and Efficiency

In dual traction for arable crops, a pair of donkeys, two oxen or two cows are employed. In the past, a pair of oxen was specifically referred to as a fidān, although today it is often used as a general term to describe all dual animal traction. Farmers universally stated that oxen in dual animal traction were the best and often described how oxen produce more even and regular furrows. This preference also probably reflects more significant functional variations in actual draught capabilities (Palmer and Russell 1993). The normal draught and work potential of animals commonly used in various locations world-wide are summarised in Table 5.5.

The general preference for oxen over donkeys would seem to be explained by the greater cumulative draught of a pair of oxen, c. 120-160 kg with 1.5 horsepower, compared to c. 60-80 kg draught with 0.7 horsepower for a pair of donkeys. Variations in draught and horsepower capabilities do not explain, however, the general preference for oxen over horses. In this latter case, it appears that the more steady and easily controlled pace of oxen results in greater consistency of tillage, a significant factor in regulating the distribution of an arable crop (an explanation also given by farmers in Greece - P. Halstead pers. comm.). Regular furrows allow for consistent light and nutrient distribution within a crop, while also facilitating weeding and harvesting activities. A single horse (or donkey) is preferred for tillage between trees and summer crops as they are more manoeuvrable.

There is a significant difference between the hills and plains of the study in the area of land that can be tilled by traditional methods in one day. On the plains, farmers stated that a team of oxen could till between 3-4 dunums in a working day. A single horse was reported to be able to till between 4-5 dunums per day, and a team of donkeys between 2-3 dunums per day. By contrast, in the hills, it was commonly stated that only 1.5 dunums of land could be tilled with a team of oxen. This latter figure falls within the lower range of previously recorded tillage efficiencies (Table 5.6) for the region and would seem to reflect the different nature of the hills and plains soils - the hills soils being much stonier, i.e. containing more obstacles. As the term fidān was also an areal measure deriving from how much land could be tilled in one day (see 5.2.2), the differences in tillage efficiencies would also seem to explain differences in the region in the reported size of a fidān .

Formerly, a large proportion of the year was spent tilling. In general terms, between late October or early November through to late January (i.e. 3 months), tillage operations were very intensive whilst the winter crops were being planted and the soil not too muddy (for example, Abujaber's descriptions of the work at al Yaduda, an early entrepreneur farm just south of Amman (Abujaber 1989, 46-49)). One man in Tibna estimated that it would take between 25 days on flat land to 30 days on steeper terrain for one man and plough team to till and sow his old share. This figure was generally forwarded by other fellaheen in the region. Tillage would also begin again in earnest from March onwards when the fallow was tilled and/or the ground prepared for summer crops. Extra labour was often required to complete, in particular, the winter operations.

For example, east of Irbid in the village of Saum, men were traditionally employed full time for tillage labour in return for a share of the crop, food and lodging. These individuals were known as harathīn and were formerly widely employed across the whole of northern Jordan (also see Dalman 1932, 147-8).

5.3.3 The Ard, Status, and Fertility

The ard, ʿawd harāth, is a powerful image for the fellaheen which can symbolise status, masculinity, and production. It has already been noted above that a fellah formerly estimated his wealth on the number of fidān which he employed cultivating his fields. In addition, I was often told, usually with a wry smile, that the relationship between the ard and the land was like the relationship between a man and his wife - to be fertile the land has to be attended to regularly. Tillage can, therefore, only be performed by men and tilling the fallow frequently promotes fertility in the following season. This analogy carries through into the name of ard components - the name for the sole/stilt is dhakar, 'male' (cf. Turkowski 1969, 28). Many metaphors between human life and cultivating the land permeate local society. For example, children and even fresh graduates (see, for example, the annual year book of graduates from Yarmouk University, Irbid) can be referred to as sanābil (the name for fully developed ears of wheat) - and the production of children adds to the status and prestige of the family group.

5.3.4 Mechanisation

The first tractors were imported into Jordan in the 1930's and from the 1970's onwards, land preparation has been predominantly carried out using tractors (Lazendörfer 1985). Animal tillage is still used in mountainous districts (such as the hills region of the study area), on small plots and in vegetable cultivation. It has been observed that in Jordan, as in other Near Eastern countries, mechanisation has not taken place at the same pace for every operation (Aydin 1990, 197). For example, in Jordan, combine harvesters are comparatively widespread - particularly on larger estates and flat terrain - but many farmers still hand-harvest, although they are likely to use a threshing machine (with hired operators) after the crop has been carried to the threshing floor. Farmers have not accepted mechanised planting (seed drills) as easily as they accepted mechanical tillage and combine harvesting (Jaradat 1988c, 249) and none of the farmers interviewed in the study area used seed drills, i.e. farmers still broadcast sow.

In the study area and for the farmers who are the subject of this investigation, tractor tillage is the main form of mechanisation used in the fields. Although some farmers own their own tractors and till their own land, most farmers hire tractors (with their owners) from other tractor-owning farmers. In 1988, in the Irbid governorate, 17% of farmers owned tractors. Of the farmers who did not own tractors but still used mechanised tillage methods, 76% rented this service from farmers who owned their own tractors (and 28% from the Jordan Co-operative Organisation) (el-Hurani 1988, 74-76).

5.3.4.1 Mechanised Tillage Implements

Mouldboard and heavy disk ploughs were the main forms of mechanised tillage implements used in Jordan in the late 1980's (Jaradat 1988a, 222-5), and were the main types observed in the study area (Plate 8). More recently, chisel ploughs have been introduced and are currently being encouraged because they cause less soil erosion (Jaradat 1988a, 224). In some ways, their action, where the soil is loosened rather than inverted thus leaving more stubble on the soil surface, is similar to the action of the traditional ard.

5.3.5 The 'Cost' of Animal and Tractor Tillage

Older farmers on the plains frequently lamented the demise of animal tillage - as noted above, the steady pace of the oxen meant a much more even crop cover could be achieved. The economics of tractor tillage in terms of reduced labour, greater speed and lower costs per unit of land apparently override such sentiments. According to plains farmers, a tractor can till in one hour what an animal with an ard can till in a day (3-4 dunum). Tractor ploughing is also comparatively cheap and cost only 1 JD per dunum (1.500 JD for land planted with trees) in 1990-92. Employing a fellah with a traditional ard, on the other hand, cost approximately 8 JD for a day's work. Most farmers who use a traditional ard, however, have their own equipment and animals.

In 1990, the ards made by the former stone mason in el-Mazār cost c. 15 JD each and a share, made by a local smith (ḫaddād) cost c. 10 JD. Modern metal ards (which come with the share attached) can be bought on the local markets in Irbid and cost 10-15 JD.

5.4 Key Aspects of the Arable Farming Year

The agricultural cycle in northern Jordan is summarised in Fig. 5.7. Details of each stage are described below in broad chronological sequence.

5.4.1 Sowing Winter Crops

The agricultural year commences around November when the first rains are expected and the winter cereals are sown. The onset of the winter rains is called the wasm ('mark') (see also Antoun 1973, 12) and is defined by the farmers themselves and in the agricultural literature as when enough rain has fallen for moisture to penetrate below the seeding depth (Stewart 1989a, 5). The date when the wasm is expected is usually given as the 15th November. This may be a modern date rather than a traditional one - it is given as the optimum date for seeding in the agricultural literature (e.g. Duwayri 1985, 131). In recent years, the rains have not arrived before December. Farmers can sow cereals before, 'afir, or after, rivy, the wasm. Most attention is paid to the correct time to plant the wheat crop. Generally, however, it is barley which is planted first. Today, most farmers sow rivy because mechanisation makes a later start possible. When the rains arrive very late (and sowing is also late) it is called lūksī. Land that has previously been fallowed (with or without summer crops) and that is going to be planted with barley or wheat is not generally tilled immediately before sowing. Otherwise, when a winter crop has been cultivated in the preceding year, the land has usually been tilled at a point between harvest and sowing.

Barley and wheat are both broadcast sown (badhara or zara'a) and the skill of sowing evenly is highly valued (Plate 9). Traditionally, only men sow winter cereals. Where animal tillage is used and more than one person is involved, the land to be sown is divided into units (using the line of a single furrow) and then each section is sown and tilled in turn. This is to ensure that the farmer only tills land that has been sown and also means that the precious seed grain will not be exposed to predatory birds for a long period. Where tractors are used to plough the land, sowing and ploughing in can be completed rapidly and so the land is not set out in the former way.

Horse bean, bitter vetch and lentil are planted after cereals, usually from December through to February (especially in the higher altitudes). There is normally a tillage episode not long before planting. This is performed to prepare the seed bed and to check weed growth. Horse bean is sown first, then followed by bitter vetch and lentil. Legumes are seemingly sown later than cereals to avoid disease problems during the humid part of the year as well as to protect them from frost (Harris, Osman *et al.* 1990, 242), but they also have a shorter growing period. Like barley and wheat, the small-seeded legumes are normally broadcast sown. In the hills, horse bean is roughly trickled (naqata) into the furrow behind the traditional ard and the seed covered in the formation of the next furrow. Trickling the smaller legume seeds into the furrow behind the ard was formerly more widely practised and traditionally performed by women. A seed tube, a būq (cf. Dalman 1932, 241), attached to the back of the ard could also be used.

It has been suggested that the best sowing depth for wheat is c. 60 to 80 mm as at this depth the seed will not be permitted to germinate with the low amount of rainfall at the beginning of the season (Snobar 1987, 36). Many farmers have commented that planting with a traditional ard, as opposed to a tractor, means both that the seed is placed at a consistently good depth and that the crop is evenly spaced in regular furrows. These two factors facilitate uniform use of available water across a cultivated plot and consequently improve yield. (This is also the principle behind modern seed drills.)

Hand-weeding is also facilitated.

5.4.2 Sowing Rates

Across the area sowing rates for wheat vary between 10 and 20 kg per dunum (Table 5.8). These rates are consistent with the rates recorded in the *Wheat Baseline Data Survey* for the higher rainfall zones (> 300 mm) of Jordan (el-Hurani 1988, 45). Seeding densely is locally referred to as badhara 'abiy and sowing sparsely is called badhara dalīl. Sowing rates on the plains are generally higher than in the hills (Table 5.7) and in the study group the average rate on the plains was 15.69 kg/dunum and 13.30 kg/dunum in the hills. The average sowing rate for the two areas combined was 14.17 kg/dunum.

Although sowing rates have been converted to rates per dunum, in fact all the farmers referred to how much seed they had sown using local measures (Table 5.3) and did not conceptualise how much wheat they had in terms of areal units. It is more appropriate to ask how much seed grain has been sown than how many dunums of wheat or barley an individual may have. On the plains, however, the sowing rate of mudd per dunum is often quoted (ṭūl id-dunum mudd) (see 5.2.1 and Latron 1936, 20) and in the hills sāʿ per dunum. The emphasis on seed rather than land seems to have been encountered by the Ottoman officials registering land in the last century (see 5.2.1 and Mundy 1992, 220 & 224).

Farmers usually stated that they planted other winter crops (barley, lentil and bitter vetch) at the same rate as wheat. As mudd and sāʿ are generally volume measures (see 5.2.1), although farmers may sow a *sa'a* of barley per dunum, they are actually sowing three quarters of the weight of a sāʿ of wheat. Farmers usually state, therefore, whether they are speaking of a mudd of wheat, for example, or some other crop.

5.4.3 Weed Control

Controlling weeds increases the amount of moisture available for the developing crop. Traditional weed management practices centre on ways of preventing and controlling the problem. In the study region, weeds are primarily controlled using fallow and crop rotation which kill and break the habit of weed cycles. In addition, the fact that most farmers today sow and till after the first rains gives the crop a competitive advantage. By tilling after the first rains, weeds which have been germinated are destroyed (Amor 1991, 201).

Another method of preventing weed infestation is to use uncontaminated seed grain. Formerly, the seed grain was used after it had been winnowed and coarse sieved but before it had been fine sieved (see Hillman 1981; Jones 1981, 1983). This meant that weeds which imitate the size and shape of the grain (as well as having the same life-cycle), so-called speirochoric weeds (cf. Kornas 1988), were dispersed and perpetuated with the seed grain. Today mechanised threshing methods and the sowing of specially cleaned seed (available from agricultural stations) is helping to eradicate these speirochoric weeds (Bunting 1960). This, necessarily, has implications for the reconstruction of ancient weed floras from modern ones (and will be discussed further in chapter 8).

Hand-weeding (see Vol. I frontispiece) is still quite frequently practised in the study area especially in comparison with other Mediterranean regions, for example, hand-weeding is rarely practised in field situations in contemporary Greece (P. Halstead pers. comm.). Weeding ('ashiba) takes place usually between January and March. In el-Hatim, Im Eiman estimated that it took four women two days to weed one dunum of wheat (and when the women are not from the family they each cost 2 JD a day to hire). Once, however, when I weeded with an elderly couple from Hartā, we managed to clear an exhausting two dunums in one day. There is, of course, considerable variation from field to field (and even, sometimes, between area to area within one field) in the amount of work required. Wheat is the main crop that is hand-weeded but barley and lentils are sometimes weeded too.

Chemical methods of weed eradication are also used in the study area, although less frequently by the farmers that are the focus of this study. (One of the main parameters used for the selection of farmers in the study group was the limited use of agro-chemicals (see 4.1.3).) Herbicides are more commonly used on the plains: they are more readily available, comparatively cheap (0.800 JD per dunum in 1990-91) and the flatter land facilitates the use of tractors and their trailing spray tanks. In the hills, difficult terrain means that plots are not usually treated with herbicides and are most often left unweeded. Farmers can spray inaccessible areas using herbicides applied from a 'back pack' with a hose attachment (I have only been told of this practice). Only wheat is usually treated with weed killers. Legumes, incidentally, are susceptible to the herbicides that are currently available to farmers.

Some weeds are allowed to grow with the crop because they can be eaten or provide fodder. For example, the seeds of jalatūn (*Tetragonolobus palestinus*) are a favourite and have a sweetness and flavour very similar to fresh-podded peas. The tap root of khurfaysh (*Marubium vulgare* L.) can also be eaten. *Convolvulus* species (mudaiyda) have 'soft' leaves which are collected for young animals. It is not uncommon to see a child collecting weeds from a field and feeding them to a goat that is 'parked' by the field edge. Many weeds continue to thrive along field edges (Plate 10).

5.4.4 Preparing the Fallow

Under the dry-farming conditions found in northern Jordan, cereals are rarely cultivated consecutively on the same plot of land as yields decline dramatically and cultivated fallow is widely employed as a mechanism to maintain yield. The theoretical basis of cultivated fallow (bare fallow and fallow with summer crops) has been considered in section 3.1. Cultivated fallow is known locally as krāb and has two primary characteristics: first, that no crop is planted during the winter period of rainfall and, secondly, that the land is intensively tilled (indeed, fallow is sometimes referred to as a 'year of tillage', sana falaha). The intensive period of tillage takes place between March and May (whether summer crops are being cultivated or not).

The first tillage episode, however, takes place anywhere between July and November (Jaradat 1988a, 212), after the stubble of the previous crop has been grazed but before the rains. When animal tillage is used, the furrows (talam) are usually widely spaced and called shaqāq which translates as 'cleaving open' (Antoun 1972, 8). The field is then left unworked until spring.

From March onwards, the land being fallowed is tilled up to four times, indeed the quality of a farmer is estimated from the number of tillage operations he performs. Where tractors are used, mouldboard ploughs are often used for the primary tillage episode and subsequently disc ploughs or even the traditional ard are employed because they create a finer, more even dry soil mulch (e.g. Plate 7). When animal tillage is used and where there is enough space for a tractor to manoeuvre, farmers prefer to cross plough, i.e. to till at 90^{o} to the previous set of furrows.

Fallowing includes both land left totally unplanted, which is locally called 'cold fallow' (krāb bārid), and that sown with summer crops, i.e. short fallow (Harris, Osman *et al.* 1991, 238). Long fallow is when no crop is cultivated until the next sowing of winter cereals, i.e. the local 'cold fallow'. In a short fallow, summer crops are generally sown during the second or third episode of spring tillage (short fallow is usually referred to as fallow with a summer crop, for example, 'fallow with watermelons'). Despite the predominance of short fallow, farmers universally praised the value of long fallow to the succeeding wheat crop. Describing wheat cultivation in Palestine in the 1930's, Pinner noted that 'The best preparation for wheat, and incidentally the most expensive, is cultivated bare fallow' (Pinner 1930, 51). (Bare, or 'cold', fallow is considered 'expensive' due to the high cost of the numerous tillage operations and because no crop is harvested that year.) A number of farmers noted that once every 10 years or so they may 'cold fallow' the land to improve the following years' yields.

Land left untilled and without a crop, so called 'weedy fallow', is rare in contemporary northern Jordan. Farmers do not really consider this a fallow period as soil moisture is not conserved. It is not called krāb but is referred to as būr, a word which is generally applied to land left uncultivated. Farmers who had left land untilled usually said they had allowed this to happen merely because they had not had enough time to prepare the soil. In one case, land had been left uncultivated because the owners (all brothers) had been unable to agree on what should be cultivated and who should do it! Because of the high percentage of co-ownership of agricultural land, this is not an uncommon phenomenon. In general, however, farmers strongly disapprove of leaving the land unworked; it is almost considered shameful.

5.4.5 Application of Fertilisers and Manure

Traditionally, fields are fertilised by dung left by animals grazing the stubble after the harvest and this practice continues to be ubiquitous. A few farmers also apply manure (zibl) collected from animal pens and sheds. I was repeatedly told that one application of animal manure would improve yields for 10 years whereas 'chemical manure' was only good for one. A number of farmers complained at the contemporary lack of availability of animal manure and emphasised the decline in the number of animals held by villagers. When manure is used it is usually carried to the fields in late winter (February and March) and left in heaps to be spread and combined with the soil during the spring tillage operations of the fallow year.

The commonly used mixed fertilisers (nitrogen and phosphate combined) are applied at the same time as sowing. Fertilisers are also applied in March and April as a supplement (a so-called 'side dressing'). In their survey of three Irbid plains villages, Karablieh and Salem noted that 90% of the farmers they interviewed used fertilisers (Karablieh & Salem 1990, 22). My general impression is, however, that the figure is somewhat lower for the study area as a whole. Many people noted that whilst fertilisers were a good investment in years of good rainfall, they were not of much benefit in bad years and indeed could be detrimental to the crop. Incidentally, Jaradat notes that land-races and local cultivars of field crops grown in Jordan are among the least responsive to fertilisers (Jaradat 1988d, 176).

The observation that fertilising does not improve yield in low rainfall years is also reflected in the fact that manuring and fertilisers are rarely used in the low rainfall areas of Jordan (el-Hurani 1988, 52). The main problem is that fertilisers encourage vigorous early growth, outstripping moisture and ultimately resulting in later drought and even plant death (Halstead pers. comm.). The major advantage of plant matter and manure over chemical fertilisers is that they provide organic matter. This improves the physical structure of the soil and increases its water-holding capacity, stability and microbial activity. Applying manure to the fallow supplements the dry mulch created by repeated tillage with organic matter.

'Green manuring', where legume plants are tilled back into the soil prior to flowering and fruiting, is not currently practised in the study area.

5.4.6 Planting Summer Crops

From the end of March onwards, summer crops such as okra, tomato, watermelon, and tobacco are sown on fallowed land. The repeated tillage operations provide an excellent seed bed and the crops draw water from moisture held in the root zone (Forbes 1979, 6). Sesame is now generally broadcast sown (sometimes mixed with soil to disperse the individual seeds more sparsely) as is tobacco. Chickpea is broadcast sown when tractors are used but is generally trickled into the furrow created by an animal drawn plough (Plate 11) (see 5.4.1 for winter legumes). The seed tube (būq), which used to be attached to the back of an ard for planting crops such as chickpea, sesame and sorghum, is no longer used. Sesame is planted at a rate of c. 1 kg/dunum and chickpea 5 to 12 kg/dunum. Chickpea and sorghum are planted before the end of the rains and sesame afterwards.

Summer fruits and vegetables are planted at a spacing appropriate to the water requirements of each species and the local soil condition (Plate 12). For example, melons and snake cucumber are spaced approximately 1 to 1.5 m apart, marrow c. 500 mm and okra only 200-300 mm. In addition, a number of seeds are usually planted in each 'hole': for example, 3 or 4 in the case of watermelon, 6 to 8 for sweet melon and 5 or 6 for snake cucumber. Tomato is cultivated from seedlings and planted c. 0.5 to 1 m apart. The summer fruits and vegetables (excluding sesame and tobacco) are also arranged in rows far enough apart to allow an ard to till a path between them as further tillage is required to keep the soil free from weeds (Plate 13).

5.4.7 The Harvest

From mid-May, the winter sown crops are harvested. Horse bean is harvested first and then followed by bitter-vetch and lentil. They are hand-pulled (i.e. uprooted) (qala'a) whilst still green (Plate 14) and left to dry in heaps in the field (Plate 15). Barley is ready for reaping (hasada) next and then, about 10 days later, wheat. When cereals have reached a stage that the farmers call qāysh, it is ready for harvesting. (During April and May farmers are very anxious about their crops due to the damage that can be done by dry winds, so-called 'khamsine' winds (see 2.2.1).) Despite the availability of cereal combine harvesters, particularly on the plains, most small-scale farmers still harvest wheat and barley by hand (Plate 16). Farmers account for this practice by explaining that they obtain better quality straw this way. Combine harvesters cut the straw notoriously high from the ground and therefore, a high portion of straw is saved by using hand harvesting methods. In recent years, straw has been very expensive and, as the direct result of the availability of subsidised imported wheat grain, is frequently said to be more valuable than the grain itself (although see the local price list - Table 6.6). Additionally, in the hills agricultural plots are often inaccessible to mechanised harvesters. When barley and wheat are hand-harvested, a toothed sickle (minjal) is usually used but they too can be uprooted (especially when crop cover is sparse). Today, the cereal sheaves are often left in the fields to dry (Plate 17) before being collected together (Plate 18) and transported to the threshing floor (Plate 19). Formerly, transportation was more-or-less immediate and the sheaves dried on the threshing floor. Reaping takes place early in the day - usually finishing well before 11 a.m.. This is so that the crop is still slightly wet with dew (nadā) and therefore, the heads are less likely to shatter (see also Hillman 1984, 120; Dalman 1933, 1-8).

It took a group of two to four people one day to harvest one dunum of wheat (each person working for approximately 5 hours), cutting the straw low to the ground. Reaping rates varied according to the density of the crop as well as the efficiency of the workers (age, experience and tools used). It is not unusual to have some people working with sickles and others uprooting the crop. This reaping rate is similar, if slightly lower, to that observed on Amorgos and Karpathos in Greece - 1 to 3 working days/stremma (1000m^2) (Halstead and Jones 1989, 47). Legumes were usually harvested at the rate of 1 to 2 working days/dunum. In a study conducted near Aleppo in Syria, it was estimated that hand-harvested legumes required c. 11.3 days to harvest one hectare (Jaubert and Oglah 1985, 28), which is c. 0.89 dunum/day. Higher reaping rates are generally expected from hired labour, although the work is generally less carefully done, i.e. there may be more grain/straw loss (cf. Halstead and Jones 1989, 47).

Although today men and women are seen harvesting side by side in the fields, older farmers describe how the work was divided between the sexes such that men cut or pulled the crop whilst the women bundled and stacked the sheaves and helped put them on donkeys (and, on the plains, camels) ready for transportation to the threshing floor. Dalman also notes this division of labour for Palestine (Dalman 1933, 45 & 53). It seems that the crop was formerly rapidly transported to the threshing ground because animals were quickly brought in to graze the stubble - either by the villagers themselves or, more threateningly, by nomadic groups (in the latter case, the farmers often feared that the crop would be destroyed by the flocks before it could be harvested). It was mainly for this reason that the time for the onset of the harvest was agreed upon (and, in addition, if some farmers completed the harvest before others, they would assist those who had not finished). Preceding the herds, in addition, the harvesters were formerly followed by gleaners (laqatāt).

No charge is made for stubble grazing - it is considered religiously commendable to allow grazing (el-Hurani 1988, 103). Farmers may sell an unharvested crop for grazing, however, if the season has been poor. In this way, farmers can gain a little compensation without spending time or money harvesting and processing a poor crop.

From June and July onwards, summer crops are ready for collection. Chickpea is ready first, at the same time to slightly after the wheat harvest. Chickpea and sesame are harvested by uprooting, but the summer vegetables and fruits are picked from the plants one by one. Harvesting and collecting summer crops continues all through the summer months, usually ending in late August to September with sesame.

5.4.8 Frīka

Between the end of the legume harvest and the beginning of barley reaping, the wheat crop is still green although the grains are fully formed. This is called the milk-ripe stage and it is at this point that the wheat can be collected for frīka. Frīka is made by taking whole wheat heads (with some straw), briefly scorching them and then separating out (or 'rubbing' - the name frīka comes from the verb 'to rub', faraka) the grains (also see Hubbard & al-Azm 1990, 105 and Hillman's descriptions for firig from Turkey: 1984, 141; 1985, 13-14). It is extremely delicious either eaten immediately as a snack or dried and coarsely crushed and used in cooking at a later date. Frīka can be made on a very small scale, often by the side of a field (Plate 20), or as a larger commercial enterprise. In the latter case, traders buy fields from local farmers and employ hired labour to reap, scorch and thresh the wheat. The wheat is normally reaped in the morning, spread across the threshing floor and set alight in the late afternoon before final threshing. (Palestinian traders, incidentally, are locally credited with the commercialisation of frīka production.) Good prices can be obtained for wheat grains processed in this way but, unfortunately, the wheat straw and chaff are lost.

5.4.9 Crop-Processing

Today, crops are almost always processed using a threshing machine (Plate 21). This means an immense saving in both time and labour - in the past, most of the summer months were devoted to crop-processing. Today, on the occasions when hand-processing can still be observed, it is usually legume crops which are being processed. Threshing machines do not leave the crops entirely free from contaminants and so some sieving and hand-picking is required to clean the crop completely. Occasionally, farmers also winnow the crop manually after machine processing.

Threshing floors are no longer communal and farmers tend to use a single small threshing floor set away from the village but close to their fields. These small independent threshing floors are scattered all across the countryside. It is currently illegal to thresh and winnow in villages due to the high quantity of potentially damaging dust created (E. esh-Shannag pers. comm.). It is interesting to note that the former site of the communal threshing floor (also referred to as mushā'a land) has frequently been converted to a school. Threshing floors are usually placed on rocky and/or hardened ground which has been brushed clean of loose stones.

Where crops are hand-processed, the sequence of events is the same as has been observed by Hillman (1981; 1984) and Jones (1981; 1984). The following description largely derives from accounts provided by older farmers of the way the wheat crop (a free-threshing cereal) was processed. After drying, the crop is heaped in mounds (bayādir) on the threshing floor. For each mound (baidar; the whole threshing floor itself is also referred to as a baidar), the animals pulling the threshing sledge (lawḥ ed-darāsa) are walked round and round to 'break' (kasara) the straw whilst the sheaves are spread and turned using a large, normally three-pronged, wooden and/or iron fork (shā'ūb) (Plate 22). The traditional threshing sledge is made of two boards of wood (normally oak) which have small pits on their underside with fragments of basalt hammered into them (Plate 23). Today, it is not unusual to see a piece of corrugated iron with rough holes punched through used as a threshing sledge (Plate 24). For bitter vetch and lentil, the crop is usually threshed by trampling alone rather than using a threshing sledge (Plate 22). The first stage of threshing takes about two to three days after which it is repeated to 'soften' (nā'ima) the wheat. Threshing has to take place when the air is dry (i.e. not in the early part of the morning), otherwise the straw will not break properly and stick to the underside of the threshing sledge. During threshing, young childen often enjoy/ed 'riding' the back of the sledge and helped break and soften the straw by acting as weights.

After threshing, the crop is winnowed using a six or seven-pronged winnowing fork (midhrāt) (Plate 26). Careful attention is paid to the correct winds and action required to complete this process successfully. It is/was usually performed by the men. The wheat grain is then coarse sieved. Today, where coarse sieving can be observed, it is carried out with a kirbāl (Plate 25). In the past, however, people describe using a larger sieve called a muqtuf. Whereas today it is mostly the women who sieve on the threshing floor, people related that the muqtuf required the 'strength' of the men (the women would, incidentally, place the grain on the sieve using the grain measurer). There is no reference to a muqtuf in Dalman's accounts from Palestine, although he does discuss a large coarse sieve (a 'sarude') (Dalman 1933, 140) which Hillman tentatively correlates to sieves used for sieving glume wheats (Hillman 1984, 126). In addition to the wheat kirbāl, there is another sieve with larger 'eyes' that is used to coarse sieve barley and chick-peas. Fine sieving (the fine sieve is called a ghurbāl) is not conducted on the threshing floor. Interestingly, the sieves were (and usually still are) made by gypsies (nawar - also see Dalman 1933, 140) who came at harvest time to exchange their goods for grain.

The final activity on the threshing floor was to measure (kāla) the grain/other products (using the sā' measurer) and put it in sacks (shuwāl). The semi-cleaned crop was then taken home to be stored or cleaned and processed further into other grain products such as burghul. Grain to be ground into flour would be fine-sieved and hand-picked at home and either ground there or taken to a mill at regular intervals during the year. All the major wadis had water-mills (tawāḥin el-mā') where grain was ground for a proportion of the flour produced (usually one sā' for up to every 6 timdād processed). Later on, engine driven mills (bābūr) replaced the water-mills. Grains were also ground at home on hand rotary querns (jārūsha) (Plate 27).

5.4.10 Crop Yield

When farmers are asked how much they expect in yield from any particular measure, the most consistent reply is that in a good year every sā' yields a shuwāl (10 kg yields 120 kg) or even more, and in less bountiful ('normal') years a mudd yields a shuwāl (20 kg yields 120 kg). Average yields of wheat in the region are approximately 60 kg/dunum (see Fig. 5.9). Where a sowing rate of (sā') 10 kg/dunum is used, such as is often quoted in the hills zone of the study area, then the expected yield appears consistent with average yields for the region. For the plains and some areas in the hills, however, twice this sowing rate is often used (mudd - 20 kg/dunum) which means double the region's average yield is expected. It has been calculated that using contemporary 'traditional' farming methods, the average yield from class I agricultural land in Jordan which receives 400 mm of precipitation (e.g. the land around Irbid) is 110 kg/dunum (1.1 ton/ha) (el-Hurani & Duwayri 1986, 67). The study area, and particularly the plains, therefore, seem to represent some of the richest agricultural land in the region (see 2.5). Farmers estimate that the same weight of chaff and straw is produced.

Some farmers thought that yields had decreased in recent years because people today took less care with their land - although there may be an element of nostalgia here. The very high yields noted by nineteenth century travellers in the Hauran (up to 25-fold returns) are thought to represent an increase in the amount marketed at that time rather than true yields (Tabak 1991, 143). Many farmers report that during the Mandate period, the study region produced a surplus of grain (and bitter vetch too) which used to be taken to Haifa for export to Europe. There was also, however, a period of very severe drought during the Mandate.

It was generally estimated that wheat could be stored for one to two years, although in 'Ajlun, some said that with the damper cooler climate, it may be spoilt after the first year. If farmers predicted that the following wheat yield might be poor (judged by the time of the onset of winter rains), they would divide the grain in two and only eat from one half while saving the second portion for the next year. Grain could be stored in mud storage bins, named kuwāra (holding between 10-40 timdād of wheat - see 5.2.1 for equivalents), in larger stone-built bins (quta') formed from linking the two central arches of the traditional house or built into the animal out-house (khān), on a high shelf (noted from around J'deta near 'Ajlun), or in cisterns (for people with a lot of land) which were carved out from the limestone bedrock (bīr), lined with chaff and straw (tibn) and capped with clay. To prevent damage by pests (especially mice), they put a plant called harmal (*Peganum harmala* L.) or a substance called jinzāra (which seems to have been commercially acquired) with the stored wheat.

5.5 Crop Rotation Regimes

The current crop rotation regimes used in Jordan are presented in Fig. 3.2 and discussed in 3.4. Above 300 mm annual precipitation, two and three course rotation regimes are used, although three course regimes are more commonly practised above 400 mm (el-Hurani 1988). Almost all the study area receives more than the 350 mm of average annual precipitation considered as necessary for the three year rotation (Keatinge 1985, 281).

Farmers in the study area are highly aware that continuous cereal cultivation seriously reduces yields and generally use crop rotation regimes with a period of cultivated fallow, where the land is 'rested'. There are two principal cropping patterns practised in the study area today. The first is a two year rotation and involves planting a winter crop (usually a cereal) every alternate year and using cultivated fallow with summer crops in the off year. As summer crops are frequently planted in the fallow year, this type of rotation is frequently referred to as a winter/summer (shatawī/saifī) rotation regime. The saifī year is considered as krāb, that is cultivated fallow. The second pattern is a three course rotation regime, locally known as muthālatha (derived from 'triple'), and generally runs cereal-legume-fallow with summer crops. Broadly speaking, the people in the hills practise two course rotations whereas three year sequences predominate on the plains and these regimes appears to have a long history in the region, at least they are fixed in the minds of the older fellaheen.

In the hills, farmers stated that winter legume crops such as lentil and bitter vetch are normally, and were traditionally, planted in the winter year of the two year rotation regime. Occasionally, however, they can be planted in the summer year of the sequence. It has been noted that winter legumes can be planted late in the hills and therefore, counted almost like summer crops (the main important difference is, however, that the farmers cannot till between the plants during spring) but in recent years, cultivating winter legume crops in the off year as winter crops is apparently practised more frequently. In other words, cereal-legume rotation regimes (i.e. the continuous cultivation of winter crops) are becoming more common. Farmers, however, note that wheat yields are lower when they are grown after winter legumes.

Cultivating winter legumes in the summer year was noted by Antoun for the village of Kufr el-Mā (located in the study area) in the 1960's (Antoun 1972, 13). Pinner also noted that in mountainous regions of Palestine legume crops could be cultivated before wheat but the preferred legume crop was chick-pea (classified as a summer crop by people in the study area), 'as the ground is ploughed twice and kept free of weeds by hoeing and weeding' (Pinner 1930, 50). In Transjordan, however, he notes that bitter vetch, in particular, was planted before wheat in poorer mountainous areas as it is harvested early (before lentil) and before most of the weeds which damage wheat have come to seed (lentil, interestingly, can be grown before a cereal but the following cereal is normally barley) (Pinner 1930, 50). Farmers in the study area maintain that the best rotation regimes include a cultivated fallow year (with or without summer crops). It is apparent, however, that in the hills, winter legumes can have a negotiable status and be substituted for cultivated fallow and are becoming increasingly cultivated in the off year. On the plains, however, they are definitely considered to be winter crops which are no substitute for cultivated fallow.

5.6 Tree Crops

Also over the summer, tree and shrub fruits, such as grape (<u>'inab</u>), pomegranate (<u>rummān</u>), fig (<u>tīn</u>), and apricot (<u>mishmish</u>) ripen and are picked. The fruits are dried (or eaten fresh, of course) and grape juice (and less commonly, pomegranate juice) is made into molasses (<u>dibs</u>). The most important tree crop, however, is the olive (<u>zaitūn</u>) - grown both for its oil and fruit. The olive harvest is the last event of the agricultural year and usually takes place between late September and October (Plate 28). A few villages in the area have irrigated orchards which are fed by spring water. The most impressive, and well regulated, orchard of the study area lies in the hills in Wadi Yabis (<u>yābis</u> translates, ironically, as 'dry') and stretches for c. 8 km along the valley (Plate 29). During summer, the villagers who own trees move into the orchard to collect and guard the fruits. Irrigated orchards can also be found on the plains, for example, in the smaller wadis that lead into the Wadi Yarmouk (Plate 31). The end of summer is marked by the olive harvest. Olive trees bear fruit every year but, generally, only produce good yields every alternate year. A heavy olive harvest can delay sowing winter crops.

Polycropping olives and cereals is practised in the study area but usually only when the trees are widely spaced, as occurs in many of the oldest orchards, or when the trees are young and, therefore, exclude less light to the developing cereal crop. It seems that polycropping is not as common a component of traditional Jordanian/Palestinian agriculture as it is, for example, in Greece (Forbes 1976). When the olive trees are young, it is also a common practice to plant summer crops (particularly onion) around them. In the hills, olives and trailing vines may be grown together either permanently, where the olive trees are widely spaced, or temporarily whilst waiting for the olive trees to be established (after approximately ten years) (Plate 30). It is generally recommended that olive trees are spaced 10 m apart or 10 trees per dunum (Duwayri 1985, 132). Vines bear fruit after approximately two to three years. The young leaves are also collected for use in cooking. Vines originating from 'Ajlun are reckoned to be of the finest quality. Olives originating from the vicinity of Tibna and Deir Abū Saīd are highly valued due to the extreme age of the trees. Old olive trees are called rūmānī, literally 'Roman', and farmers like to boast that this means their trees date from the Roman period.

Olive yields can vary widely depending on the year and the age (or even 'character') of the trees. The amount of oil produced ranges from 1.5 kg per 20 kg (mudd) of fruits in a poor year to 4 or 5 kg of oil per 20 kg of fruits from mature trees in a good year. Today, olives are usually taken to mechanised pressing plants to extract the oil. The payment for processing the oil is in kind - 1 kg of oil is taken for each 10 to 12 kg produced. In the hills in particular, a few farmers still extract the oil non-mechanised means (the oil is extracted first by crushing and then using a press).

According to local tradition, the olive tree is like a badawīya (woman bedouin) as she is strong and survives almost all conditions and treatments while always producing. The fallāha (woman fellah), although strong, is more like the wheat plant and requires more tending.

5.7 Animal Husbandry

Both plains and hills villagers keep livestock, although the numbers kept by local farmers are said to have declined in recent years, especially on the plains. This trend contrasts strongly with the increase in animal numbers held by groups living in the semi-desert (bādiya) (see Lancaster & Lancaster 1991, 131). Goats, sheep and cattle are kept by villagers. Although most herds contain both sheep and goats, all goat herds are quite common around 'Ajlun in the evergreen oak forest (Plate 32). Older farmers boasted of the large flocks and herds that were formerly held. Ownership of livestock is an expression of wealth within the region and even today (if slightly less so), when people wish to emphasise the importance of an individual or group, they will say how many animals they own/ed (cf. ownership of oxen formerly - see 5.3). Offering an animal for a religious feast, celebration or guest is a very important component of hospitality and religious life. Mansaf, a dish made of goat (or sheep) in a yoghurt based sauce (either from fresh yoghurt or dried jamīd (see 5.8) or both) placed on a bed of rice or burghul, is the standard feast food (for both bedouin and fellaheen).

As well as an apparent reduction in numbers of animals held, there have also been some qualitative changes in the types maintained: from local to new breeds ('Syrian' goats and

'Dutch' cattle) and from sheep and goats to cattle - farmers say that two cows, for example, are easier to herd than 20 goats. Cattle yield milk for longer than either goats or sheep. Local cattle are said to milk for 6 months, goats for 5 months and sheep for 3 months. Konikoff estimated that, for local Palestinian breeds, cows yield 500-700 litres annum, sheep 40 litres/annum and goats 70 litres/annum (Konikoff 1943, 52). Yields are likely to be higher with recently introduced breeds.

Animals are mainly fed on wheat chaff and straw, barley, bitter vetch, lentil straw, and until recently, 'white' sorghum. Wheat and barley chaff and straw are called 'white straw' (tibn abyad) while the straw from legume crops is referred to as 'red straw' (tibn ahmar). Different grades of chaff and straw are distinguished and refer to the crop-processing stage from which they derive (i.e. fine-sievings, coarse sievings etc.). (Long good quality straw (qash) was formerly, and sometimes still is, used in basket work.) 'Red straw' is generally considered more nutritious than 'white straw' but is more suited to sheep and goats than cattle because it can damage cattle teeth. The better quality of 'red straw' claimed by local farmers is confirmed by experimental evidence. Investigations conducted into the dry matter digestibility and the crude protein content of legume straw (chickpea, lentil and horse bean) reveal significantly higher values than found in either wheat or barley straw (Capper 1990, 154-155). Sheep and goats are generally fed 'red straw' (most commonly) or 'white straw' both of which can be mixed with pieces of bitter vetch seeds. Cattle are fed 'white straw' with bitter vetch pieces. Donkeys, mules and horses are fed on 'white straw' and barley. Camels (formerly owned by plains farmers) seem to eat everything - both 'red' and 'white straw', bitter vetch pieces and barley. The fodder is stored in animal out-houses (khān), caves ('araqān), specially constructed buildings (tibbān), or old houses. This type of stored fodder is especially important for livestock during the winter months.

During the spring, there is good grazing available in the study area. The forested and deforested areas of the hills are covered with lush ground vegetation. Local villagers and pastoral nomads come into the area to graze and browse their flocks at this time. Villagers also collect wild grass, drying it on house roofs, before storing it (Plate 33). The trees provide year-round grazing for goats (although there are government restrictions) who appear to be able to climb almost to the uppermost branches. Acorns from the evergreen oak, *Q. calliprinos*, are occasionally collected for fodder. Plains villagers can take their animals out to the east into the bādiya to graze. Some villagers said that cattle used to be driven down into the Jordan Valley for the spring (which arrives slightly earlier there). Over the summer, animals are grazed on the stubble. Pastoral nomads come into the area at this time and the plains, in particular, are dotted with their traditional goat hair tents (bait esh-sha'r) and not-so-traditional trucks. Villagers can also move into tents during the summer (for harvesting or moving with their herds), but do so less than before.

Farmers and their families tend their own animals, but they can also hire shepherds. Shepherds (rā'ī) are often paid in money for their services today, but, formerly, they were employed for a return in kind receiving one in three or four of the new born lambs kids plus a small quantity of wheat. In the past, 'arāb (nomadic pastoralists) were hired to tend the flocks for the whole village (a practice more noted for the plains than the hills). Very wealthy people would have their own 'arāb to manage their flocks. The animals would be grazed together, but return to their home for milking (Plate 34). People to herd cattle were also hired in the past. They were paid in wheat, not young animals. Incidentally, one of the former major causes of village disputes was caused by animals destroying crops so guardsmen (natūr) were hired by the village (also paid with wheat) to protect the crops.

5.8 Local Diet

The great hospitality of people in the study area means that food is almost always the first way visitors are made aware of the diversity in the local farming economy. Recent dietary changes also serve to highlight recent changes in farming conditions and practice too.

Many traditional foods in the study area mix milk and grain products. For example, the main food encountered by nineteenth century travellers in the area was a food called kishk but this is not such a strong staple today (Basson 1981). Kishk is made from yoghurt and burghul wheat which is fermented for a day, made into balls and left to dry in the sun and then ground into granules (FAO 1991, 60-61). It can be stored for a very long time and reconstituted when required. Along with bread, burghul wheat (see Avitsur 1975; Hillman 1984, 135; 1985, 15, for preparation sequence) was a regular staple but it has been replaced to a large extent by imported rice. There is a wide range of fermented milk products which are still popular: laban (yoghurt), labana (strained yoghurt - often stored in oil), shanīna (yoghurt whey), jamīd (defatted dehydrated yoghurt - used to make mansaf), samna (purified fermented butter), and jibna (cheese stored in brine). For the hills farmers studied, home production is still relatively common and women use a hide bag (shiqwa) to make butter and other products (Plate 35).

Bread is now almost always made from wheat but older farmers recall that it could be mixed with other grains or entirely made from barley or sorghum (e.g. kiradīsh - see above). Villagers say that more meat is available - especially chicken which is intensively produced in local poultry farms. Legumes, the 'poor man's meat', are less commonly consumed. The main meat based feast dish, mansaf, has already been mentioned (see 5.7). Olive oil, rather than samna, is today more commonly used in cooking. More fresh vegetables are available, many of which are cultivated under irrigated conditions in the Jordan Valley. With the increasing availability of fresh vegetables and market produce, less is preserved by villagers. Storage is not as important as it formerly was and new houses are built without the storage facilitates that were once so integrated into the form of the house.

5.9 Summary

In this chapter, the crops cultivated and the nature of farming in the study area have been outlined. Crops are divided locally into winter and summer crops - the season referring to the time of planting. The principal winter crop in the study region is durum wheat and most farmers plant one of the hybrid varieties derived from local land-races. Barley is also cultivated and the local land-race is still cultivated by many farmers. The two primary legume crops of the study region are bitter vetch and lentil, both winter crops which are planted immediately after wheat and barley.

Summer crops are planted from March onwards when the rainy period is almost over. They primarily include summer fruits and vegetables such as tomato, cucumber, okra watermelon, and other melon types. Small quantities of sorghum, either 'white' (for fodder) or 'yellow' (for brooms), are also cultivated. Chick-pea, the third major legume crop of the area, is a summer crop and generally planted in March/April. Sesame and tobacco are also important.

The two principal events in the arable year are planting and harvest of winter crops. Delay or premature action at these times can significantly reduce yields. The time to plant wheat is signalled by the onset of winter rains. The legumes are the first to be harvested (they are uprooted by hand) and are followed by barley and then wheat. The winter crop harvest usually begins in May and ends in late June. The summer crops, starting with chick-pea, are ready next and the harvest continues throughout the summer until the sesame harvest is completed in September. Before the introduction of machine threshing, crop-processing lasted from June until September.

In order to maintain yields, wheat is not planted every year and, in the study area, it is either planted every second or third year. Two year crop rotation regimes predominate in the hills where either a legume crop is cultivated or fallow (usually with summer crops) is practised in the 'off' year, i.e. cereal-legume and cereal-fallow rotation regimes. On the plains, three year regimes predominate and both fallow (again usually with summer crops) is practised and a legume crop is cultivated in the intervening years. According to local farmers, fallow is practised to 'rest' the soil. The main way manure is applied to fields is by stubble grazing.

Tree crops, and particularly olive, are widely cultivated and the olive harvest is the last event of the traditional agricultural year. There are a number of notable spring-irrigated orchards in the area although most trees are cultivated without irrigation. There has been a large increase in olive cultivation in recent years both in the hills on former areas of forest and on land that, before land registration, was reserved for arable cultivation.

Although the numbers of animals held by local villagers appear to have decreased in recent years, animals are still an important part of the local economy. Sheep, goats and cattle are held and a wide range of milk derived products are produced - many of which can be stored for long periods. Most older farmers own a donkey which can be used to carry fodder, draw or carry an ard, or indeed, carry the farmer. Oxen have almost entirely disappeared as the main traction animal and most land is now tractor tilled.

In this chapter the nature of farming in northern Jordan has been discussed. The critical factor, however, which has been partially in the background - except in terms of looking at the points when labour is required - is the people themselves. The next chapter focuses on farmers and how they make their day-to-day and year-to-year farming decisions.

Chapter 6 Agricultural Decision-Making

This chapter concentrates on the crop management decisions taken by 'traditional' farmers (contemporary and recent past) - decisions which operate/d above and beyond the environmental limitations of the Mediterranean climate. The scope of decisions taken range from short-term reactions to daily and weekly occurrences, e.g. the first rains; to intermediate and longer term strategies such as choosing which crops to grow and the crop rotation regime practised on any one piece of land and finally, to choosing whether to plant trees - a long-term commitment. In supplying their needs farmers are constrained by a number of factors both environmental and cultural - their physical environment, the requirements of the crops under cultivation, the supply of labour, and the size and tenure of their land-holding unit. In addition, contemporary traditional farmers also face a rapidly changing world - technology, the influence of an expanding world market and international agricultural policies have had an impact on even the remotest farmer. The emphasis of the chapter is placed on explaining the rationale behind both past, but particularly present agricultural practice.

The following discussion is primarily based on the results of 72 interviews with local farmers - the 'farming background' of the study group (Table 4.1b). The discussion, however, also includes additional comments either made by these 72 farmers or by others from whom a complete set of answers was not obtained - either for circumstantial reasons or because they were no longer involved in the production of arable crops. It is also worth reiterating that the main themes of the standard interviews were originally formulated using experience gathered whilst living in village households. The information on how farming practice has changed was largely provided by the group of older fellaheen who were interviewed in 1992 (see 4.1.2). In other words, this discussion is informed by a range of conversations and experiences and not only confined to the results of the standard interviews.

6.1 The Farmers

Contemporary farming in northern Jordan is practised along a range of scales from small family units, holding a few dunum of land and cultivating for household consumption, to large commercial enterprises. The farmers that are the focus of this study, as defined in 4.1.3, operate at the middle to lower end of this scale and use improved agricultural techniques only selectively. In fact, a large proportion of the land farmed in northern Jordan is owned by farmers operating these comparatively small, low technology units.

Agronomists working in the area have frequently lamented the lower take-up of modern techniques compared with other countries in the region (Arabiat *et al.* 1983; ICARDA 1984; el-Hurani 1986; Jaradat 1988; Karablieh & Salem 1990). This situation, however, is changing rapidly (cf. el-Hurani 1988).

This section examines the farmers whose actions are studied in this chapter. First, the social changes that have affected farming practice during this century will be summarised and secondly, the division of agricultural tasks in the household (the pool of agricultural labour) will be explored.

6.1.1 20th Century Transformations

When asked what is the main difference between contemporary and past life in the villages, older farmers usually emphasise three themes: first, the way in which people used to work together; secondly, the monetary nature of contemporary existence; and finally, the introduction of mechanisation. These three themes summarise the great rural transformation that has taken place during this century, although they omit one of the greatest changes - the large increase in population.

In the early part of the century, particularly prior to land allotment (1930's-1950's), older farmers recall that village communities were essentially self-sufficient and that this was achieved largely because everyone worked together (i.e. villagers were interdependent). The kinship bonds were very strong. Agricultural decisions were often made by agreement on a village or 'ā'ila (tribal unit - see 2.7) level - defining either sections of the village or even linking broader associations together (e.g. the confederation of villages based at Tibna). Under the system of communal land-holding (mushā'a) which operated in most of the study area, shares in agricultural land were regularly redistributed between 'ā'ila who then redistributed the shares between households. This involved a high degree of co-operation as land was rigorously allocated according to its quality as well as each 'ā'ila and household's entitlement. In the study area, allocation was performed using 'the rope and the pebble' (al-ḥabl wa al-ḥaswa): the ropes were used to divide up land units and the pebbles were 'flown', i.e. tossed like a coin (distinctive stones or small objects held in someone's hand or placed in a heap of sand were used to select land units randomly) (cf. Bergheim's description of the redistribution in Palestine during the last century - 2.6.2).

Other important agricultural decisions were also taken together including what crops to sow and where to sow them as well as when to harvest. It was important that the crops were planted in continuous units and harvested together to prevent damage by animal grazing. The land set aside for fallowing also provided an area for winter grazing. Although farmers tilled, sowed and maintained their own plots individually, harvesting together was vitally important. It not only protected the harvest from grazing damage, but also prevented people taking more than their allotted share.

Today, the more immediate family (household) rather than the extended family forms the decision-making unit. In 1972, Antoun noted that lineage obligations in Kufr el-Mā had decreased since the independent registration of land ownership. He continues, 'there was a growing independence of separate households as a result of an agricultural regime suited to a single family exploitation and an occupational structure producing increasing economic differentiation' (Antoun 1972, 75-6). The extent of family ties should not be underestimated, however, as extended family members will support each other in particular investments or arranging marriages, but the extent of the ties and the obligations they involved have certainly declined. In a study of the village of 'Ain, slightly south of the study area, Taminian summarises the situation well, 'whereas households were organised around 'ā'ila(s) now it is more the other way round, that 'ā'ila(s) are organised around households' (Taminian 1990, 21).

In the early part of the century, most villagers were involved in subsistence activities. Until even as late as the 1950's, a limited range of goods entered from outside (and often these would be associated with, for example, the brideprice). Labour was exchanged between households without requiring payment although a small gift in kind (e.g. a sā' of flour) may have been expected and/or future willingness to help should the need arise. Even as late as the 1950's, it was estimated that the income of the village of Saum was less than 100 lirā per year.

Today, by contrast, farming is rarely the main source of income for villagers and most households do not rely on agricultural production to supply their requirements. Most sons now find employment outside the agricultural sector, primarily in administration, education or the military. In addition, a fair proportion attend university, or some form of higher education, and are increasingly deserting the villages for a career in Irbid or Amman and some spend a period of time working in the oil states (although demand for labour from the oil producing Arab states has diminished in recent years, reducing the flow of remittances (Commander & Burgess 1990, 44)). In 1985, Seccombe, in an assessment of labour migration in north-western Jordan, documents that for the village of Sammū less than 9% of the workforce was employed in agriculture (Seccombe 1987, 123).

Despite the large increases in population seen in the study area, the fact that so many people are now employed off the farm has meant labour shortfalls (el-Hurani 1985, 82; Aydin 1990, 198; Richards & Ramezani 1990). Agriculture tends to be practised by the older generation and usually plays a supplementary, although not to be underestimated, role. Many of the older farmers involved in farm management have spent a number of their younger years in the army and so receive an income in the form of a pension (16 years of service are required). Mechanisation has filled some of the labour shortfalls incurred by so many people working off the farm, along with hired labour. Mechanisation, however, has also been partially blamed for exacerbating rural unemployment and migration to urban areas.

The take-up of agricultural technology by small-scale farmers has been comparatively slow, or at least uneven, but the adoption of mechanised tillage (see 5.3.4) has meant a considerable labour saving (cf. 25-30 days to till and sow a former share of arable land compared with just one day today) - although the size of land units held is smaller. The break-up of communal land tenure and shortage of family labour has affected animal-holding. With less available land for grazing and less labour for herding, fewer animals are held by villagers. The impact of mechanisation and off-farm employment will be considered below in relation to their effect on different members of the household.

6.1.2 Agricultural Roles

On a very simplified basis, women's tasks generally involve squatting and bending whilst men's tasks generally involve upright movements. As noted in 5.3.3, animal powered tillage is a male task and the same is also true for other animal powered operations (e.g. threshing). Traditionally, it is also the role of men to broadcast seed, till, harvest (a bending movement - an exception to the above generalisation!) and thresh. Although women today can be involved with sowing and reaping wheat, formerly their traditional role in the field was mainly to weed, bind and stack wheat sheaves and to assist with sieving on the threshing floor. Women plant and harvest other crops - particularly legumes and summer crops - but cultivating wheat and seed bed preparation is traditionally a male occupation. Women's main involvement with wheat comes in the later stages of crop processing and cleaning and food preservation/preparation.

It is evident that with the increasing adoption of farm technology (mechanised implements and chemicals), women are losing involvement with some realms of agricultural activity. Machines are gradually replacing former animal powered operations (male tasks), but they are also taking over domains which were traditionally female, such as grain cleaning and hand-weeding. Machines are almost always a male preserve, although women may assist. As machines are usually hired with their owner-operators, women may be excluded because they are not allowed to associate with men who are not well-known to their family. Day-to-day tasks around the home have been reduced - bread and milk-products can be bought and pottery/clay skills (making pots/containers, clay ovens and other utensils) are dying out. Women's domestic activities remain absolutely essential to the survival of the unit (Rogers 1989, 152), however, and they cannot generally be replaced by male labour (D. R. Tully 1990, 73). The younger generation of women tend to have negative perceptions of subsistence activities. Many of these women are, like the men, entering the workplace and their expectation is not to have to work in the fields - they aspire to live and work in the cities and speak using the 'town' (Damascus-like) dialect and not the local 'village' one (interestingly, young Jordanian men from the study area are keen to identify themselves with their local origin and prefer a version of the latter!). These trends, however, are more evident on the plains (especially near Irbid) and for the villagers of this study, women are still called upon to assist in weeding, the care of summer crops and harvest. There is a strong element which still values locally grown home-prepared products (particularly food), although the skills to produce them are not automatically being passed on to the younger generation.

The timing and input of male and female labour is similar to that noted in other areas of the Near East. Men work in seasonal bursts (preparing seed beds, sowing cereals and at harvest) whereas women have a more consistent year round input, but increase their contribution at critical periods such as harvest (Myntti 1984 in D. R. Tully 1990, 75). Women tend to be involved with producing home-consumed produce, or items that can be sold from home to neighbours (such as eggs and milk-products). If produce is to be sold on the market, however, this is generally a male domain as is negotiation and contact with agricultural agencies.

Labour is not usually hired by the farmers of this study. Male labour, however, is available and can be 'purchased' daily from the market in Irbid. These men usually come from either Syria or Egypt and appear in great numbers at particular times of the year - harvest being one of them. Female hired labour tends to be provided locally and performed by poorer women (sometimes relatives). The perceived lower status of hired agricultural labour is another factor influencing younger people not to work full-time on the land. Farmers in this study, if they do hire labour, are most likely to hire local women to assist with the legume harvest. As with family labour, hired women are a source of intensive non-mechanised labour (cf. Rassam and Tully 1986, Doreen Tully 1990, 75).

Children were an important source of labour and still are, although formal schooling has decreased their involvement. Although education was introduced comparatively late into Jordan (only comprehensively after independence in 1946), it rapidly became an accepted and desirable idea for both village boys and girls (Wåhlin 1987, 171). This not only meant that qualified adults could take up jobs beyond the village bounds, but also that children could not play such a large part in daily agricultural events. Tasks traditionally performed by children (both boys and girls) are weeding, helping with the harvest, animal tending, and general fetching and carrying. One of the reasons given for the decrease in numbers of animals held by villagers was insufficient labour (referring to child labour) to tend the flocks.

6.1.3 The Farmers in the Study Group

In total, 72 complete interviews of farmers are included in the analysis of contemporary farming practice. These include 53 farmers whose fields were sampled for their weed flora (4 farmers had two fields sampled twice and the people who owned the fields which were formerly weedy fallow were excluded) and 19 whose fields were not examined either because they were not cultivating wheat that year, had used weed killers or, very occasionally, were unenthusiastic about allowing me to enter their fields.

Most of the interviews were conducted with men as the primary informants, but usually included observations made by other family members. Two interviews were solely conducted with women: in the first case, a widow farmed her own land (see 4.1.1) and in the second, it was the wife who primarily organised farming activities as her husband was away in the army and anyway 'she knew more about it' (comment by other family members). Otherwise, as stated above, the primary informant (the 'farmer') was generally male. He was not, however, automatically the head of the 'household'/'family'. As the people managing the fields were often old men - and especially when the household did not depend on agriculture for their main source of income - it was possible that they would be the 'nominal head', but that, in practice, many important family decisions were taken by others (and especially members who brought in an outside income). On the other hand, sons who undertook most of the agricultural work might defer to their father's uncles' judgement on how the land should be managed. Agricultural decisions may also be taken between close family members - something which is particularly true when land is co-owned by a related group (also called mushā'a tenure).

In section 4.1.3, the general criteria of the farmers interviewed were outlined. The 72 farmers interviewed include 26 farmers from the plains and 46 farmers in the hills. The youngest was 30 and the oldest almost 90 years old. The average age of the farmers was 55.7 years old (Table 6.1a). 45 farmers were between 40 and 60 years old (Table 6.2). In Table 6.3, the age and occupation of the farmers is shown. 75% of farmers who were working full-time on the land (either fellaheen or ex-military men) were more than 50 years old. Most of the people farming the land who were aged 60 or less either had another occupation or had been in the army for a substantial time, i.e. they were receiving another income (34 compared with 21 farmers who had regularly worked the land). Approximately equal numbers of farmers with another (primary) occupation worked in skilled and non-skilled occupations (11 and 13 respectively). 15 of the 17 people over 60 years old had only ever farmed.

A relatively equal proportion of farmers on the plains and in the hills considered themselves to be true fellaheen (22 out of 46 in the hills and 14 out of 24 on the plains) (Fig. 6.1 and Table 6.4). In the hills, comparatively more farmers were receiving an army pension - 10 compared with 2 on the plains. In the evergreen vegetation zone, 12 out of 13 farmers were full-time farmers (fellaheen or ex-army). Farmers whose primary occupation was skilled ('educated') were concentrated on the plains and farmers whose occupation was manual ('labour') were concentrated in the hills.

Farmers in the hills generally cultivated slightly smaller areas of wheat than plains farmers (Table 6.5 and Table 6.1b & 6.1c). The average area of wheat cultivated by all the farmers was 13.94 dunum (Table 6.1a). If the average sowing rate is 14.17 kg and the average yield is six-fold (see 5.2.10), then the average total wheat yield is 1185.2 kg. In a very good year, where twelve-fold yields may be expected, this rises to 2370.4 kg. For the Near East and North Africa, estimated cereal consumption is 200 kg per year (Tully 1989, 24). If it is assumed that households contain 10 people and that cereal consumption is in the form of wheat, then only in the best years are all cereals requirements met by the farmers' own production. It would seem, however, that people on the plains fare better than those in the hills. In the hills, the total yield ranges between 945.6 kg and 1891.3 kg (using averages presented in Table 6.1b) whereas, on the plains, the range is between 1661.6 kg and 3323.1 kg (using averages presented in Table 6.1c).

The market prices for the main crops cultivated in northern Jordan are given in Table 6.6. Using the price of wheat (130-140 JD/ton) as the basis for calculation, hills farmers in the study group earned between approximately 123 JD and 265 JD and plains farmers between 216 JD and 465 JD. This, of course, is the selling price rather than the buying price (which would be lower), although the salesman commented that the government will buy wheat for slightly above his selling price.

35% of the farmers in the study group used animal powered tillage (Table 6.7). Animal tillage is, however, primarily practised in the hills - only 2 plains farmers (8%) did not use tractors (Fig. 6.2). Equal numbers of hills farmers used tractor and animal tillage, although comparatively more farmers in the mixed and evergreen forest vegetation zones used animal tillage (Table 6.7). One third of the fellaheen used animal powered tillage and 7 out of 12 ex-army people (Table 6.8). All the farmers with a primary occupation that was skilled used tractor tillage. 6 of the 7 farmers who cultivated more than 20 dunum of wheat used tractors (Table 6.9) - a result which is partially explained by the larger areas which are cultivated on the plains and the use of tractors on the plains. Smaller tracts of land, however, are less amenable to tractor tillage.

Most plains farmers owned no livestock (20 out of 26), whereas in the hills, only 14 farmers out of the total of 46 did not own animals (Fig. 6.3 and Table 6.10). In the hills, 28 farmers owned up to the equivalent of 3 FAO livestock units (e.g. up to 30 goats/sheep or 3 cows). Ownership of livestock will be discussed in greater detail in 6.3.3.5. 45 farmers owned a donkey(/s), a horse(/s) or both (Table 6.11). More hills than plains farmers owned donkeys and/or horses. Also, no farmers with a primary skilled occupation owned either donkeys or horses, but 9 out of 13 farmers with an unskilled primary occupation did (Table 6.12) - this also reflects differences between the occupations of plains and hills farmers. 25 of the 45 farmers who owned donkey/s and/or horse/s used animal powered tillage and these animals normally pulled the ard (Table 6.13). The comparatively small area of land cultivated (c. 14 dunum) is insufficient to warrant farmers supporting a pair of oxen.

6.1.4 Conclusions

Within three generations, the nature of rural society has profoundly changed. From grandfathers who were fellaheen and depended upon the land sprung a generation which mostly joined the army and worked for the unification and defence of the Hashemite Kingdom. Now, most of the children of these people do not work in agriculture and the army is still a favourite occupation. The reliance on other forms of income, from army pensions to foreign remunerations, has led to the coining of the phrase 'part-time farming' (e.g. Arabiat and Snorber 1984; Mundy and Smith 1990). Farming is now an occupation primarily for older men. Within these three generations there has also been a change from communal land tenure to private ownership. The size of land-holding units held by farmers has also decreased.

The farmers interviewed include 46 farmers from the hills and 26 farmers from the plains. Most farmers were over 50, with an average age of c. 55 years. Half the farmers interviewed were life-long farmers, fellaheen. Of the other half, 12 were ex-army people and 24 had another primary occupation. The average area of wheat cultivated by farmers in the study group was c. 14 dunum, an area that would yield enough wheat to feed a household of ten people in good years. In most years in the hills, however, there would be a shortfall. This reflects the supplementary nature of farming to household incomes.

One third of farmers used animal tillage, although these were concentrated in the hills (only 2 plains farmers used animal tillage). This reflects the comparatively quicker adoption of agricultural technology by plains farmers and the suitability of their land to mechanisation.

The farmers who form the study group are at the smallest-scale end wheat of farmers included in the *Wheat Baseline Data Survey* (el-Hurani 1988). Most of the study group farmers are broadly consistent with the full- and part-time owner-cultivators described by Lazendorfer (1985) and Ghannam (1990, 105). In addition, 12 farmers also rented the land they were cultivating with wheat (see 6.3.3.2 - for discussion of contemporary land tenure). There is, in addition, a particular emphasis in the study group on farmers who use traditional farming methods - a deliberate bias of the study (see 4.1.3).

Within the last 60 years, the region has seen a tremendous growth in population. The area has turned from, in general, a net agricultural exporter to a net importer unable, by a large margin, to support itself. Vast tracts of good agricultural land are covered with new developments and villages are spreading and merging at an alarming rate. Mechanisation also has implications for the scheduling of work, women's labour loads, and even the provision of animal manure (cf. D. R. Tully 1990, 80-83). Despite the changes, it is important to emphasise that the people of northern Jordan are no strangers to change. Nineteenth century history, for example, was a time of reassertion of Ottoman authority, land reformation, and population migration (see 2.5).

6.2 Making the Most of It - Short-Term Decisions taken during the Agricultural Year

During the agricultural year, the main aim of the farmer is to secure their chosen crop. Furthermore, in order to maximise yields during that year farmers 'should':

1. maximise the water available to the crop for the critical periods of plant growth.

This can be achieved by planting the crop at the optimum time to receive the greatest benefit of the winter rains, using an appropriate sowing rate, and removing weeds which compete with the crop for moisture.

2. maximise plant nutrient supply.

This can be achieved by fertilising the crop and removing weeds which compete for soil nutrients.

Farmers, however, do not always seek to maximise yields.

6.2.1 What to Sow

6.2.1.1 Choice of Winter Crop

Wheat is the primary winter crop in the study area and for most arable farmers, wheat takes primary position in the crop rotation sequence. Farmers consider what they will sow in the light of their family's requirements and what they consider can be supported on their land in any particular year. They also consider market prices (especially for summer crops). These factors will be discussed further below (crop rotation regime - 6.3). If it is predicted that rainfall will be poor, farmers may change what they had intended to sow in order to secure a crop that will succeed (i.e. choose a plant that is more drought resistant). On the other hand, they will always take advantage of a good season and perhaps, for example, sow more wheat.

For farmers who cultivate wheat, there is often a resistance to cultivating the latest high-yielding hybrid varieties (el-Hurani & Duwayri 1986). Farmers believe that although in good years the new varieties may yield well, in poor years they are likely to do no better than their own wheat, and may even fare less well. In addition, they are expensive to buy (and seed for the next year is often carried over from the previous one) and require expensive fertilisers in order to achieve their potential. Many farmers say that they do not have the cash to invest in the new varieties and furthermore, if the crop does fail, then they have lost not only the crop, but money too. They prefer to have lower yields which they feel are more assured.

6.2.1.2 Choice of summer crop

Summer crops, if cultivated, are sown in the spring of the fallow year (see 3.1.5). At this point, farmers know how much rain has fallen during the winter and therefore, are able to assess what the land can support. Farmers also test how much moisture is stored in the soil by digging into the ground with their hands to see when they reach moister levels. The closer the moister soil is to the surface, the more moisture is contained within the whole profile. With this knowledge, farmers decide whether to plant a summer crop, which one to grow and what sowing rate (or space between plants) to use. It is interesting to note that one of the reasons for the slow uptake by farmers of new varieties of winter chickpea is that they view the ability to know how much rain has fallen as more advantageous than the better yields that can potentially be produced by the new varieties (Tutwiler & Mazid 1990). Minimum precipitation requirements for some of the summer crops of the Mediterranean region are given in Table 3.1.

The decision about which crop to sow also depends, importantly, upon family requirements and marketability. On the plains, sesame, watermelon, melon, and tobacco are commonly cultivated and their dominance probably reflects their wider marketability. Tobacco, for example, has been very popular in recent years and has been more profitable than wheat or other summer crops (Duwayri 1985, 127). So profitable are summer crops that one farmer was encountered who had ceased cultivating winter crops altogether and, instead, was cultivating summer crops every year. Other summer crops cultivated on the plains include broom sorghum, tomato, cowpea, okra, and sunflower, but these tend to be cultivated in small patches and used for household consumption. The availability of tomato, cucumber and other crops grown under irrigated conditions in the Jordan Valley and brought to Irbid for sale perhaps deters market involvement for plains dryland farmers in these vegetable products. In the hills tomato and okra appear particularly popular, the former used primarily for home consumption, but some of the okra was certainly being marketed. Chickpea is universally popular. Typically, most of the farmers in the study group planted a little of many types of summer crop, the variety providing diversity in the household diet. In addition, growing a variety of crops offsets the effects of failure of any one type (cf. Forbes 1976). In sum, there is a distinction between crops grown for cash and those grown for home consumption and more crops seem to be grown for cash on the plains than on the hills (which are more remote from the markets in Irbid). A similar phenomenon has been observed in north-east Syria (Harvey 1980, 15).

When asked what were the main differences between the old days and contemporary farming, most of the older farmers pointed to the expansion in the cultivation of summer crops as one of the main changes. Both the types and quantities of summer crops cultivated seem to have expanded, and particularly in the past 20 to 30 years. Some farmers linked this expansion with the influx of Palestinian refugees (and Palestinian farming experience) in 1948 and 1967. Certainly, the older farmers working in the area who were of Palestinian origin, boasted of the knowledge they had brought with them, but this also reflects local rivalry between the two groups. Pinner, however, observing farming practice in the region in the 1920's did note that bare fallow (fallow without summer crops) was more common in the Hauran and Golan than it was in Palestine (Pinner 1930, 52). The expansion in the cultivation of summer crops also certainly reflects the expansion in cash cropping seen in many developing countries and the imperative to produce a crop every year (Dixon, Jones & Sherman 1989, 32). Finally, it is probable that part of the reason for the continuation of the practice of fallow in northern Jordan is linked to the profit that can be gained, or the money that can be saved (because these goods do not have to be bought), from the cultivation of summer crops (also see below).

6.2.1.3 Choosing Bare Fallow (fallow without summer crops)

Bare fallow is still practised in the study area and not only in those parts where average annual precipitation levels are less than c. 325 to 350 mm - the approximate level required for the cultivation of summer crops (Harvey 1980, 8). Bare fallow is either practised as a response to periodic drought or to ensure future success of the cereal crop.

Bare fallow may be adopted when insufficient rain has fallen in the preceding winter. Cultivating summer crops in the fallow year depletes some soil moisture, but generally not so much as to cause the following crop to fail. If farmers decide that insufficient rain has fallen during the winter they may choose not to plant summer crops as planting them may jeopardise the success of the following cereal crop. On the other hand, farmers cultivating in lower rainfall areas may plant summer crops in a year of exceptionally good rainfall.

Bare fallow may be practised to ensure the success of the following cereal crop and it has been observed that the greatest value of bare fallow occurs when a wet year is followed by a dry year (see 3.3.1). If farmers wish to ensure, rather than maximise annual cereal production, bare fallow is the most secure option to choose. The role of bare fallow in the cropping regimes practised in the study area will be discussed further in 6.3. Some farmers commented that they may occasionally bare fallow as it helps to maintain long-term productivity. They often assess whether their land requires bare fallowing based on the height of the preceding cereal crop. Many of the older fellaheen say that they like to bare fallow the land at least once every 10 years (like manuring - see below). In the study group, the only farmers who had practised bare fallow (8 from 72) in the previous season were fellaheen (see below and Table 6.35).

6.2.2 When to Sow

6.2.2.1 Wheat

Wheat can be sown before ('afir) or after (riyy) the rains. Today, most farmers sow after the onset of the rains, and in the study group 69 farmers out of 72 had sown their wheat crop after the rains (Table 6.14). All three farmers who had sown before the rains were farming in the hills vegetation zones with evergreen trees, and they owned the land they were cultivating. Of the three, there was one 'educated' farmer and two fellah - and they all used tractor tillage.

Both practices - sowing before and after the rains - have advantages and disadvantages. Sowing before the rains maximises yield as the crop has the benefit of all the rain, but also means that weeds are encouraged because they also have the benefit of all the rains as well. As a result, the field may require more weeding. Early sowing also has the disadvantage that if the rain does not occur relatively soon afterwards, then the seeds are vulnerable to predators. Also, if some rain falls but there is then a gap, the grain germinates but afterwards dies (P. Halstead pers. comm.). On the other hand, sowing before the rains can prevent an enforced delay later - rain leaves the soils of the study area very sticky and unworkable for a day or two, so that if it rains for a number of days, sowing can be seriously delayed and consequently yields may be drastically reduced. Most farmers say that early sowing is 'better' but are careful to qualify this statement - they are keen to see how the season develops (i.e. the timing and nature of the first rains). One farmer commented that early sowing was especially beneficial for wheat sown on thin soils - presumably, the additional moisture makes up for the lack of moisture that would be stored in deeper soils. Finally, a few farmers commented that it was better to wait to sow and till until after the first rain because the rain softened the soil and made tilling easier.

Delaying sowing until after the onset of rains means that farmers can judge how much rain will fall during the season. Generally, the earlier the rains begin the better the season and the greater the yield (cf. Stewart 1988; 1989a; 1989b). Waiting is advantageous because, if a poor season is predicted, farmers can, for example, sow another crop (e.g. barley is more tolerant of drought than wheat) or sow the crop at a rate which will prevent the crop reaching maturity with insufficient moisture to complete development. The final advantage is that sowing after the first rains kills weeds which have been germinated by the rains and gives the crop a competitive advantage.

Today, as noted above, sowing after the onset of rains is the dominant practice, but farmers commented that this had not been the rule previously. The change in practice was explained in a number of ways. Farmers who used tractors commented that tractors enable them to sow and till all their land in a single day. Therefore, part of the reason farmers delay sowing is because of this factor. This cannot, however, be the whole reason because most of the farmers who used animal tillage (i.e. generally owned their tilling equipment and animals) also waited until after onset of the rains to sow. As noted above, later sowing allows predictions to be made about the forthcoming season and adjustments made to the crop sown and sowing rate. It also significantly reduces weeds. All these reasons encourage later sowing, but an older farmer also explained that early sowing used to be necessary because they had to ensure that some of the seed was in the ground before the rain fell because it took up to 30 days to sow and till an old share of land not just one day (see 5.3.2). Waiting until after the onset of rains could mean that the ground was unsuitable for sowing for a long period and the success of the whole crop could potentially be put in jeopardy. He also explained that early sowing produces better yields and that weeding was not such a problem because labour was more freely available. Finally, he commented that contemporary farmers do not rely on agriculture in the the same ways as their farthers and grandfathers did and therefore, people today could 'afford' the lower yields and potential crop loss associated with delayed sowing. The fact that farmers are cultivating smaller plots of land today (plus the use of tractors noted above) means the risk of not finishing sowing is also far less.

Earlier this century, Pinner notes that sowing before the rains was widespread in Transjordan and the Hauran (unlike in Palestine) and he links this to the more common practice of bare fallow (Pinner 1930, 58). During bare fallow, the soil is tilled numerous times which loosens the soils so that it can be tilled before the rain arrives - without tillage, rain is generally required to 'soften' hard-baked earth.

Although farmers can sow and till very rapidly with tractors, if they hire people to till the land for them, they are not always in control of when the operation takes place as they have to wait for machines to become available. Sowing may be delayed even when animal tillage is practised due to shortages of labour (cf. Halstead 1990, 188).

6.2.2.2. Other Winter Crops

Most attention is paid to when the wheat crop should be sown. Barley is generally planted at the same time as wheat or slightly earlier so that it does not compete with the wheat crop for the best time to be sown. Once the cereals are sown, the legumes are planted (usually starting in January). They may be planted slightly later in the hills to avoid potential frosts.

6.2.3 How Much to Sow - Sowing Rates

6.2.3.1 Wheat

Sowing rates for wheat vary according to rainfall and higher rainfall zones are generally more thickly sown than lower rainfall zones (cf. el-Hurani 1988, 44). In the study area, farmers in the hills generally sow less densely than farmers on the plains (see 5.4.2, Fig. 6.4 and Table 6.15), although the rainfall for the two regions is very similar. Farmers largely explained this difference in terms of the soils encountered in the two regions. The plains farmers boasted that their soils were very deep and therefore, stored more moisture which could support denser crop cover. There is, however, within this general trend some variation which can only partially be explained by the fact that some of the hills soils are quite deep and that areas of the plains (particularly towards the eastern and southern sides) receive less moisture.

Farmers may sow more densely in years when they expect good rainfall or more lightly in poor years. Farmers may also sow densely when they wish to crowd out weeds on a particularly vulnerable plot - especially if there is a shortage of labour for hand-weeding (also Maekawa 1984, 87; Halstead 1990, 188). This latter practice does have a drawback because, although weeds may be crowded out, there may be insufficient moisture to finish crop development (cf. Amor 1991, 201). Sparse sowing can be beneficial to the farmer as it requires less seed (Halstead 1990, 190). Low seeding rates have also been associated with an abundance of land and the tillering rate of the species planted (Halstead 1990). In the study region, most farmers use a very similar variety of *Triticum durum* - which incidentally, is reported to tiller well (Percival 1921, 207) - so the influence of tillering rate is difficult to assess. As the areas of land cultivated by the study group are comparatively similar, the effect of land availability on seeding rate is also limited (if anything, larger areas of land are sown more densely, but this is associated with location on the plains).

6.2.3.2 Other Winter Crops

Precipitation, soil depth, the physiological requirements of the crop, availability of labour and seed, also affect the sowing rates used for barley and the winter legumes.

The winter legumes were traditionally sown by trickling the seed into the furrow behind the ard (or sometimes using a seed tube). Today, it is more common to sow legumes, like the cereals, broadcast. This is partially due to the adoption of tractor tillage where the speed of the operation and the furrows are not suitable for trickling. The adoption of broadcast sowing when animal powered tillage is used, however, perhaps is associated with insufficient labour to sow the crops in the traditional way. Broadcast sowing is quicker and more labour efficient, but generally requires more seed.

6.2.3.3 Summer Crops

The sowing rates and spacing used for summer crops cultivated in the study area were given in 5.4.6. The sowing rate of crops such as chickpea and sesame and distance between plants such as watermelon and tomato can be altered according to the amount of moisture assessed to be contained in the soil (see 6.2.2).

6.2.4 Hand-Weeding

Weeding is generally considered to represent good crop management. Removing weeds provides more water, nutrients, light and space for the growing crop and consequently, improves yield. In addition, some weeds harbour disease and pests. Finally, weeds within a crop make harvesting and crop-processing more time consuming and increase the probability of including weed species within the crop seed (they also mean that the quality of the straw and chaff is reduced which also reduces its palatability and market price). Hand-weeding reduces weed infestation during the year of cultivation, but fallowing and crop rotation help to prevent the problem.

32% of farmers in the study group hand-weeded their wheat crop (Table 6.16). Proportionately, slightly more farmers practised hand-weeding in the hills than did on the plains - 35% and 27% respectively (also see Fig. 6.5). Comparatively more weeding is practised in the vegetation zones with deciduous trees (Fig. 6.6), but it is difficult to interpret the higher figures recorded in these zones, especially as the numbers concerned are comparatively low (it does not, for example, seem to be associated with sparser sowing rates - Table 6.15).

Hand-weeding can be viewed in two ways: first, as a practice that is employed when it is required and consequently it is possible to look at weeding as a response. For example, as weeding is practised by more farmers in the hills it can be postulated that hills fields require more weeding. Even from casual observation, this is indeed true (see chapter 7 for fuller exploration!). Secondly, and on the other hand, more weeding in the hills may also reflect different social/cultural conditions of the farmers there - the availability of labour to undertake weeding or even an attitude that expects weeding to be done (as, for example, is expressed by farmers who call themselves fellaheen). The second approach - weeding reflecting social or cultural conditions - will be explored first as it appears to be the dominant factor.

It might be predicted that older full-time farmers (i.e. fellaheen and people who had been in the army) would weed more than younger farmers (especially those who had another occupation) as they both have more time and are potentially more familiar with the older traditions where weeding is usually considered an essential component of good crop management. In the study group, it is indeed the fellaheen and the people who had formerly been in the army who practised weeding more often (13 out of 36 and 7 out of 12 respectively) (Fig. 6.7 a and Table 6.17a). None of the farmers who had a primary skilled occupation removed the weeds from their crop and only 3 out of 13 farmers who had an unskilled primary occupation hand-weeded. For farmers cultivating in the hills (where the fields are weedier), 8 out of 22 fellaheen weeded, 5 out of 10 ex-army farmers and 3 out of 11 farmers with an unskilled primary occupation (Fig. 6.7b and Table 6.17b). Over half of farmers (both hills and plains) in the older age group categories (>60 years old) practised weeding (Table 6.18). These results, therefore, seem to indicate that weeding is indeed a practice associated with older full-time farmers. Interestingly, in terms of proportions, weeding was most often practised amongst farmers who were receiving an army pension (farming is often partly considered as a 'hobby' by these farmers).

Availability of family labour might also be expected to affect whether weeding is practised. Children are, traditionally, a source of labour for weeding and therefore, it might be predicted that farmers with larger families would hand-weed. This is, however, not borne out by the results (Table 6.19). It is difficult, however, to make comparisons because the number of farmers with small families was very low (most had more than 5 children). For farmers with large families, however, those with more than 8 children did weed their fields slightly more often than those with 6 to 8 children (9 out of 34 (27%) and 11 out of 29 (38%) respectively) (Fig. 6.8 and Table 6.19). This perhaps hints that the number of children may affect the decision whether to weed or not. The number of children in a family is, anyway, a somewhat simplified statistic as is does not encompass either the gender or age of the child. For example, it is more likely that a young daughter of 12 years of age would be involved with weeding than a 21 year old son who is attending university or working away from the village.

As renting usually discourages the farmer from investing in the land, it might be expected that farmers who rent would not practise weeding as often as those who own their land. Of the 15 farmers who rented, only 2 hand-weeded whereas 21 of the 57 farmers who owned their field (either outright or with relatives) practised weeding (Fig. 6.9 and Table 6.20). It is interesting to note, in addition, that a markedly higher percentage of farmers who own their fields with other members of the family practice weeding, i.e. practice good crop management. This could reflect the availability of more labour to weed or perhaps that there is a greater obligation to practice good crop management when other members of your family/group are involved.

Ownership of livestock will be discussed in greater detail below, but at this point the link between weeding and livestock will be examined simply in terms of livestock requiring fodder and weeds providing some of the fodder requirement. In this respect, it might be expected that farmers with animals will weed their fields. The results are interesting and suggest that the relationship between weeding and livestock is affected by scale. Taking the two categories 'no animals' and owning animals equivalent to up to 1.0 FAO livestock units (i.e. 1 cow or 10 goats/sheep - see 4.3.3.2), weeding is indeed practised by farmers who own animals - with 8 out of 34 (24%) and 9 out of 14 (64%) farmers practising weeding (Fig. 6.10a and Table 6.21a). Above 1 FAO livestock unit, only 6 out of 24 (25%) farmers hand-weeded. The lower incidence of weeding in this group suggests that farmers with lower numbers of animals may hand-weed to provide fodder, but that when farmers own more livestock, fodder is provided from elsewhere (either from grazing/browsing in the forest, grazing in the bādiya, or is bought in). Below 1 unit, it would appear that weeds are a useful source of supplementary fodder (and probably help to maintain or improve household milk supplies), but that above 1 unit, weeds provide insufficient fodder and also detract household labour from the important task of herding (i.e. bulk fodder provision). The difference in weeding pattern also perhaps reflects farmers who are keeping animals for home consumption and those who are raising them for commercial purposes. It has been noted previously that animal ownership is greater in the hills and more weeding is practised in the hills. Taking the hills alone, the same trends are (even more strongly) visible (Fig. 6.10b and Table 6.21b) which reflects the fact that most of the people who owned animals were located in the hills.

It has been demonstrated above that gross differences in sowing rate are largely linked to environmental factors (precipitation and soil type), but that sowing rate is also affected by certain objectives of the farmer, for example, wanting to crowd out weeds or save seed. In the study group, weeding was less frequently practised by farmers sowing at a higher rate (Table 6.22) which would seem to suggest that denser/thinner sowing does eliminate/encourage weeds. This result is slightly more complicated than it appears, however, because plains fields, for example, tend to be sown more densely and are less weedy, but plains farmers are less likely to own livestock and so less likely to collect weeds as fodder. It has been noted previously that sowing before the rains may encourage weed growth, but all three plains fields that were sown before the onset of rains were not weeded (table not shown).

Crop management practices which are likely to affect weed growth and therefore, affect whether the fields require weeding include: crop rotation regime/previous year's crop (crop rotation and fallow are important methods used to control weeds), fertilisation, and tillage method. The association between crop rotation regime and weeding is shown in Table 6.23 and between the previous year's crop and weeding is shown in Table 6.24. The current year's 'cereal' (i.e. the crop being weeded or not) is always wheat.

5 out of 10 fields cultivated using a cereal-legume rotation regime were weeded and this is, in terms of percentage, the crop rotation regime which is most often weeded (Fig. 6.11 and Table 6.23). Farmers commented that continuous cultivation of winter crops increases weed cover and therefore, the fields generally require more weeding. One of the main benefits of fallowing the land, according to farmers, is that it removes weeds. 7 out of 26 (27%) farmers using cereal-fallow and 11 out of 35 (31%) farmers using a 3 year rotation regime weeded their wheat crop. The evidence, though inconclusive, does suggest continuous cultivation requires more weeding.

Approximately equal percentages of farmers weeded their crops who had in the previous year practised bare fallow - 3 out of 8 (38%), fallow with summer crops - 15 out of 48 (31%), or cultivated legume crops - 5 out of 15 (33%) (Table 6.24). The field that had been previously cultivated with wheat was not weeded. A link between weeding and a particular previous crop is, consequently, not evident. All the fields that had been cultivated with a legume crop in the previous year, but were being managed under a 3 year rotation regime (i.e. two years ago there was a fallow year) were not weeded. This perhaps suggests that fallow effectively reduces weeds even two years after implementation. There is, however, some ambiguity in the evidence linking weeding and crop rotation regime (and previous year's crop), although it does appear that fallow does reduce weed cover. The ambiguity is partially due to the small numbers involved in the discussion, but perhaps also suggests that other factors, such as the availability of labour, have a more profound influence on whether a field is weeded or not.

All arable areas in the study area are grazed after harvest. The droppings left by grazing animals contain seeds which contribute to the following year's weed flora. Adding manure potentially adds more weed seeds, but can also, by providing additional nutrients, make a more favourable growing environment for weed growth. The latter also applies when chemical fertiliser is added. Although the numbers are very small more farmers who apply manure (2 out of 3) and use chemical fertilisers (6 out of 9) did weed their wheat (Table 6.25). These figures also probably reflect the tendency for farmers who fertilise their land to practice other 'good' management practices such as weeding.

Farmers say that tractor powered tillage tends to decrease weed cover (although they also note a few weeds such as *Cynodon dactylon* (najil) which persist and are even encouraged by tractor tillage). During animal tillage, however, farmers are careful to pick out weeds, such as *Cynodon dactylon*, which are not normally killed by the dislodging action of the ard. In the study group, more farmers weed their fields who use animal tillage (Table 6.26) which might suggest that tractor tillage reduces weed cover. This difference, however, would seem to represent gross differences between the hills and plains (social factors such as the labour supply and weeds providing supplementary fodder and the fact that hills fields are generally weedier) rather than differences in tillage technique.

Weeding is generally considered to represent good crop management and was formerly widely practised. Today, the situation is somewhat different and the majority of farmers interviewed did not practice weeding, although compared with other areas of the Mediterranean, it is still comparatively common. Hand-weeding is influenced by social factors (e.g. farmer's occupation, labour availability, ownership of livestock, land tenure), crop management practices (e.g. crop rotation regime, sowing rate, manuring) and vegetation zone.

6.2.5 Fertilisation

Like weeding, applying manure to fields is considered to represent good farming practice. Only three farmers from the study group had fertilised their wheat during that season using animal manure (1 from the plains and 2 from the hills) and 9 said they had applied chemical fertilisers (5 from the plains and 4 from the hills). The low number of farmers applying manure partially represents a decrease in this practice (on the plains, for example, people often stated the lower numbers of animals held by villagers meant that dung was less freely available), but many farmers also stated that it was only necessary to apply manure once every 10 years. Therefore, manuring may be a more common practice than it would appear from the cases observed here. This, in some ways, makes manuring more a medium-term crop management technique rather than a short-term one. Chemical fertilisers, which have short-term benefits, are comparatively expensive and it was apparent that some of the farmers would say they had used them when, in fact, they had not. It is not certain, therefore, whether all the farmers who said they had used chemical fertilisers had done so. The figures suggest (very tentatively) that chemical fertilisers are more regularly used by farmers on the plains. The higher sowing rates and returns of plains farmers may indicate that investment in fertilisers is more worthwhile on the plains. Plains farmers are also closer to the main agricultural research stations.

Two of the farmers who had applied manure were fellaheen and one had an unskilled primary occupation. Of the nine farmers who used chemical fertilisers, 4 were fellaheen, 4 were ex-army farmers and one had a primary occupation which was skilled (Table 6.27). It is difficult to draw conclusions from these numbers, except to observe that most of the people fertilising their land are full-time farmers. All except one of these farmers owned their land and all the farmers who used animal manure owned their land outright (Table 6.28). This would seem to reflect the fact that people who own their land often practice better crop management.

All the farmers who used animal manure owned livestock, not surprisingly, and two of these owned more than the equivalent of 60 sheep/goats or 6 cattle, i.e. 6 livestock units (Table 6.29). Chemical fertiliser was used by 5 people who owned no animals as well as 4 farmers who owned animals (owning more than the equivalent of 1.0 livestock units). This perhaps partially reflects the fact that farmers who do not own animals do not have access to animal manure, but that animal ownership (especially in large numbers) often indicates wealth and these farmers can afford to purchase fertilisers (which are notoriously expensive).

Interestingly, none of the farmers who practised cereal-legume rotation fertilised their land in any other way than by grazing (Table 6.30). It was not explicitly stated, however, that the wheat crop was not fertilised because legumes enriched the soil. Similar proportions of farmers who practised cereal-fallow and three year rotation regimes fertilised their wheat. Most of the fields which had been fertilised had been fallowed (bare fallow or fallow with summer crops) in the previous year, although one had been cultivated with a legume crop (Table 6.31).

In conclusion, where animal manuring was practised it was done by three farmers who owned their own land and held livestock. Chemical fertilisers are more commonly used on the plains where they are potentially more available and beneficial to crop yields. Decreasing ownership of animals on the plains also means that less manure is available for manuring. All except one of the farmers who fertilised their land with manure or chemical fertilisers were full-time farmers. It is interesting that none of the fields cultivated under a cereal-legume rotation regime was additionally fertilised. The primary method by which land is fertilised in the study area is, however, by stubble grazing.

6.2.6 Conclusions

The decisions taken during the agricultural year show how farmers respond to environmental conditions, family needs and provision of labour. For example, weeding is practised more frequently in the hills where fields are weedier, but will also be practised more often by farmers who need the weeds to provide fodder for their animals. Weeding is also more frequently practised by full-time farmers (especially ex-army farmers who seem to farm the land as a 'hobby' in part) who have, by definition, more time to weed.

The decisions taken by contemporary farmers are highly complex and balance the need to secure a yield with limited labour whilst minimising cash inputs. For example, farmers today sow wheat after rather than before the onset of rains - a strategy which generally means reduced yields. In employing this strategy, however, there are benefits - farmers reduce the need to weed and help to avert planting an inappropriate crop or using a sowing rate which cannot be supported (sowing after the rains means that they can make a better assessment of how much rain will fall). They do not maximise yields and instead, seem to employ a strategy that will provide a reasonable yield without incurring great losses. In the past, farmers had to ensure a yield without the security of another income. This meant sowing before the rains, weeding and fertilising the crop and generally, doing as much as possible to secure the success of the crop.

6.3 Sustaining Year-to-Year Production - Crop Rotation Regimes (Middle-Term Decisions)

Beyond the next harvest, and to sustain production on the same piece of land, farmers need to maintain good soil conditions - maintaining moisture and fertility levels, good soil texture, and preventing erosion - as well as keeping the area free from pests and disease. In the study area, crops are rotated to ensure productivity and they are usually rotated in combination with a period of cultivated fallow. Cultivated fallow is the traditional management technique used to restore soil moisture and fertility and reduce weed and pest infestation (see 3.1). Most of the study area receives enough precipitation to allow for complex rotations (see 3.4 and 5.5) and both two (cereal-fallow and cereal-legume) and three year rotation regimes (principally, cereal-legume-fallow) are practised, but two year rotation regimes are generally followed in the hills and three year regimes on the plains.

This section discusses why different crop rotation regimes are practised in the study area, examines why cultivated fallow has persisted, and explores the reasons behind recent changes in crop rotation regime. Although employing different crop rotation regimes is termed a 'medium-term decision' in this study - chiefly because regimes can be changed within a few years - cropping sequences have longer-term implications for society as well as crop productivity.

6.3.1 Crop Rotation Regimes Practised by the Study Group

The crop rotation regimes practised by the study group are shown in Table 6.32. In the study group, and as noted previously, three year regimes dominate plains cultivation and two year regimes are prevalent in the hills (Fig. 6.12). Only 4 of the 26 farmers from the plains applied two year rotation regimes and 13 of 46 hills farmers used three year rotation regimes. Comparatively more farmers in the degraded deciduous vegetation zone practised three year crop rotation (Fig. 6.13). The standard sequence for three year rotation regimes is cereal-legume-fallow (usually with summer crops), the so-called muthālatha, but hills farmers sometimes reverse the fallow and legume years so that the sequence runs cereal-fallow-legume. This observation perhaps reflects a greater flexibility among hills farmers. 9 out of 46 farmers (20%) in the hills practised a cereal-legume rotation regime and 13 out of 46 had cultivated a legume crop in the previous year (Fig. 6.14 and Table 6.33). Comparatively more farmers had cultivated a legume crop in the year prior to wheat in the evergreen vegetation zone (Fig. 6.15). Generally, it was evident that hills farmers were more familiar with changing their cropping sequence. According to older farmers, in the past, two year regimes had dominated in the hills, but it seems that three year regimes are becoming more popular along with cereal-legume regimes (although it should be stated that more unusual regimes were sought out in this study). The cereal-fallow (i.e. a winter crop/summer crop) regime was only practised by 50% of hills farmers in the study group. Most of the farmers practising cereal-legume rotation regimes had been using the regime for at least 3 cereal years (i.e. 5 years) and three were using the cultivated *Vicia sativa* in their rotation - a comparatively recent introduction encouraged by local farming agencies. On the plains, by contrast, there seemed to be a stronger concept of a fixed way to rotate crops.

The different rotation regimes employed by farmers in the study group raise three main questions - why do two year regimes predominate in the hills and three year regimes in the plains? What prompts farmers to alter their cropping sequence and why are hills farmers apparently inserting a legume crop more often into their traditional crop rotation regime? Why are plains farmers more 'set in their ways'?

6.3.2 Environmental Factors Affecting Crop Rotation Regime

6.3.2.1 Precipitation

The major natural environmental factor affecting the choice of rotation regime is precipitation (see 3.2.2). Most of the study area receives more than enough precipitation to allow for complex rotations (>350 mm) and indeed, in the hills around 'Ajlun, average annual precipitation is c. 550 mm. Precipitation, therefore, does not account for the variation observed, although it does allow for the diversity employed.

6.3.2.2 Soil Type

Farmers on the plains frequently boast of their good soil and often state how deep it is and how this means it stores moisture well. The hills soils, by contrast, are often shallower (and stonier) and therefore, able to store less moisture (see 2.3.2 and 3.1.4). The greater capacity of the plains soils to store moisture means that they require less frequent fallowing and so allow for more complex rotations. Soil type, therefore, certainly provides a partial explanation for the employment of two course rotation regimes in the hills and three year regimes on the plains.

Soil type, however, does not entirely explain choice of crop rotation regime. In the hills, even where deeper soils are thought to exist (such as in wadi bottoms), fields are managed under both two and three year rotation regimes. In addition, not all fields in the hills are fallowed (i.e. those managed using a cereal-legume regime). On the plains, some of the areas which practise three course rotation regimes have shallow soils and, in addition, two course crop rotation regimes are beginning to be adopted by some farmers. Some farmers on the plains are selecting to grow (fallow with) summer crops for two years rather than a legume crop and then fallow before the wheat year.

6.3.3 Cultural/Social Factors Affecting the Choice of Crop Rotation Regime

The choice of crop rotation regime appears to be affected by a number of factors which are more linked to the people rather than the environment. These cultural and social factors are labour, land (tenure and size of land-holding unit), animal ownership, and what shall be referred to as 'economic' factors (market and government policy). Although discussed in isolation, the interdependence of the factors will become evident.

6.3.3.1 Labour

> 'These manual operations, however, do not affect the profit of the Fellah. His work has no money value for him ... In a place where labour commands no price there is no need to be particular about time and to despise slow work ... What is the use of time-saving implements and quick-working cattle if the work can be done also with light implements which he acquires for a few pounds and which last him all his life, sometimes being left over for his son?'
>
> Elezari-Volcani 1930, 39-41

These observations by Elezari-Volcani - although at the same time idealising the traditional life of the fellaheen as well as demeaning it - help to highlight some of the main changes that have occurred during this century for rural people. He also underestimates the awareness of traditional farmers of the value of labour.

Despite the massive increase in population seen in the study area, the most frequent complaint of older farmers is that there is no-one to do the work. In section 5.1, it has been noted to what extent farming has become a 'part-time' occupation or an occupation only practised full-time by the older generation. Many contemporary shifts in agricultural land usage can be viewed as the results of insufficient labour. People today are certainly aware of the concept that 'time is money'.

The main way in which availability of labour potentially affects contemporary crop rotation regimes in the study area is that legume cultivation is very labour intensive as it is hand-harvested, and therefore, insufficient labour may lead to the elimination of the legume crop from the rotation sequence. It has been shown above that the decision to weed is affected by labour availability - the occupation of the farmer and the number of children. In the study group, cereal-legume rotation is practised by full-time farmers (fellaheen and ex-army farmers) and farmers with an unskilled primary occupation (Table 6.34). These are the farmers who tend to spend more time working the land and so there may be a tentative connection with labour availability. Farmers, however, did state that the labour required for legume cultivation was a factor influencing their choice of crop and has led to the decreased cultivation of legumes in the study area.

Of the 10 farmers who had previously cultivated a legume crop on their land (this includes 3 year crop rotation regimes in the hills where a legume crop preceded the cereal crop), only one had a skilled primary occupation, i.e. had an occupation which usually meant that less time is invested in the land (Table 6.35). It should be noted, however, that most of the farmers with a skilled primary occupation farm on the plains and they generally have a summer crop preceding the cereal year so, once again, the results represent a complex interaction of factors.

The number of children in a household appears to have had no effect on the choice of crop rotation regime or the previous year's crop (see Table 6.36 and Table 6.37). Most farmers in the study group have children (and usually more than 5).

It might be expected that with the reduction of labour available for crop management, there may be a reduction in the use of cultivated fallow. The adoption of mechanised tillage, however, seems to have compensated for labour shortfalls and the ability to plant profitable summer crops also means that cultivated fallow is maintained as a component of crop management. Interestingly, farmers who use tractor tillage for sowing winter crops often use animal powered tillage for their summer crops and not only because animals are more manoeuvrable. They are willing to use animal tillage in summer crop cultivation because the returns are good. Summer crops are also more likely to be tilled to remove weeds either before or after the winter crop harvest as labour to do it is available then.

In general, farmers commented that people do not till the land as much as they once did and lament the decreased availability of animal powered tillage for sowing winter crops despite the amount of work it entailed. Most farmers reflected that the returns they received reflect, along with 'the will of 'Allah', the time and care invested in the land and more tillage is connected with better crop management. Many declared that, as they were working alone, it was difficult for them to tend their crop in the way they preferred (hand-weeding, as another example, is not as intensively practised as it was in former years) and they had to accept reduced yields.

6.3.3.2 Contemporary Land Tenure

The categories of land tenure used in this study include two renting categories (sharecropping and renting for cash) and two categories where the land is owned (either outright or with other family members). As a result of land registration, most local farmers own their land. Indeed, most farmland in Jordan is owner-operated and only approximately 16% of it is rented (Karablieh & Salem 1990, 9). In Jordan, the formal rules governing the devolution of land through inheritance mean that each member of the family has a share in the agricultural lands. Males have equal shares whilst females are given half the share of their brothers. Each block of land is divided into a number of plots held either individually or jointly (in which case the respective shares of the co-owners are stated) (Mundy 1990a, 9-10). In the official statistics for Jordan, the point is often made that land is highly fragmented and that individuals own small dispersed plots. Mundy observes that for the Wadi Zarqa, although technically this may be the case, the way the land is managed means that larger jointly held plots should form the basis of any analysis i.e. ownership patterns do not always correspond to patterns of farming management (Mundy 1990b, 164). During land registration, the British officials attempted to allocate land in continuous units. Most farmers interviewed, however, tended to own more than one unit (usually two or three) representing different qualities of land.

79% of the farmers in the study group owned their own land (Table 6.38). For farmers in both the hills and the plains, most farmers said they owned their land outright (Fig. 6.16). 25% of farmers in the study group owned their land with a close relative or farmed it for a relative. Proportionately more of the plains farmers owned their land with a relative (9 out of 26 (35%)) compared with 9 out of 46 (20%) hills farmers. This, however, may be an underestimate of the true figure as farmers tended to say they owned land when they, in fact, only technically owned a share of it. In families particularly known to me, a whole family may have shares, but, typically, the father and perhaps one son managed the land whilst the rest of the family were engaged in other occupations. Although members of the family knew how much land they 'owned', or the extent of their share, the whole land was farmed as a unit. It is likely that land which was said to be owned entirely by the farmer was owned by him/her and children whereas land owned with a relative was owned with a more distant relative or a close relative who had a separate household. Although women technically have a share in the land, their right to ownership is often overlooked or their share simply taken over by their male relatives. (I once sat in on a conversation between a woman from Irbid and one from a nearby village who were discussing the fact that people in the towns are more scrupulous about allotting women their share in the land.)

Of the 15 farmers who rented their land, 9 farmed for a share of the crop (generally one third) and 6 rented for money (Table 6.38). Although the figures are small, renting appears to be relatively more common in the hills. 8 of the 15 farmers who were renting land were sharecroppers based in the hills.

Farmers usually rent their fields on a year to year basis and do not know definitely whether the tenure will be renewed or not. The returns for the sharecropper range from one third to one half of the crop and are based on their input - whether they supply labour, tillage and seed. Renting on this short-term basis generally encourages farmers to maximise production without investing in the longer term fertility of the land. It has been noted already, for example, that farmers who rent land are less likely to manure or weed. Thus it might also be predicted that farmers who rent the land will cultivate the land every year and/or fallow less often. The results from the study group are equivocal, but there are some interesting trends (Table 6.39a). 4 of the 15 (27%) farmers who rented were practising continuous cultivation (cereal-cereal and cereal-legume regimes) compared with 7 of 57 (12%) farmers who owned their land. This perhaps indicates that continuous cropping is more commonly practised when land is rented. In addition, the only field which had been cultivated under a cereal/cereal regime was rented. The low numbers involved make this observation somewhat ambiguous. The proportion of hills farmers practising cereal-legume rotation who rented is slightly larger than those who owned (3 out of 12 (25%) and 6 out of 34 (18%) - Table 6.39b). Only 1 of the 12 farmers who rented in the hills, however, used a three year rotation regime (i.e. produced a cereal only once every 3 years). In conclusion, the evidence suggests that farmers who rent the land tend to cultivate every year whereas owners may use fallow. In addition, farmers who rent balance short-term returns against poor yields and continuous cropping by using cereal-legume rotation, i.e. a regime that produces a crop every year, but also helps to maintain the fertility of the land.

Two farmers who rented their land had practised bare fallow in the previous year, although the majority of farmers practising bare fallow (6) owned their land (Table 6.40). It has been stated above that bare fallowing is associated with good farming practice and it might be expected that farmers who rent would not bare fallow. In the two cases where the rented land was bare fallowed in one case rainfall had been felt to be too low to grow a crop and in the other it was the farmer's first time cultivating that particular field (i.e. he had not controlled the previous year's cultivation). 5 out of the 6 farmers who owned their land and practised bare fallow, owned the land outright. The cultivation of summer crops is popular both amongst farmers who rent and own the land they are cultivating - it allows the land to be 'rested' (in part), but also means a crop is produced. Finally, it should be stated that people who rent land do not always choose their own crop rotation regime - it may be dictated to them by the land-owner. This may account for some of the ambiguity in the results. The same may also be true for farmers who cultivate land with relatives - the farmers managing the land may be obliged to follow a crop rotation regime which is not their own choice. Overall, these results suggest that, although tenure may influence the choice of rotation regime, other factors are also influencing farmers' decisions.

6.6.3.3 The Impact of Land Registration on Arable Farming

The way decisions were taken under the communal land tenure system (mushā'a) has been discussed in 6.1.1. Many decisions which are often now taken on an individual or household basis were formerly negotiated by the tribal unit (the 'ā'ila). Under the system of mushā'a, farmers acquiesced to a communally agreed, more-or-less fixed, crop rotation regime. Under this system two year regimes dominated on the plains and three year regimes dominated in the hills. Land registration has permitted more variation. It seems to have allowed the greater cultivation of summer crops (fallow land is no longer communal grazing territory) as well as meaning that winter legume crops are more often cultivated in the 'summer crop' rather than the 'winter crop' year of the typical hills two year rotation regime. It is also allowing some plains farmer to omit cultivating legume crops altogether. Land registration is allowing for more intensive land utilisation (incidentally, the intention of the reforming British officials).

Individual land-holding would also seem to allow for more opportunistic continuous cultivation. For example, during the spring of 1992 it was noted that a number of farmers were cropping wheat for a second year. Farmers explained this in a number of ways. First, the rains had begun early and had been strong and so farmers felt there was enough moisture to support a second year of wheat cultivation. Secondly, this was the year after the Gulf War when there were import restrictions placed on Jordan. So, farmers were cultivating wheat to insure against potential shortfalls as well as taking advantage of an extremely wet winter.

One older plains farmer from the village of Zaḥar commented that the traditional three year crop rotation regime used on the plains may become a four year regime with two years of fallow - one weedy for animal browsing and the other bare fallow (and with summer crops) - before wheat. This illustrates the extent to which crop rotation regimes on the plains were formerly integrated with the need to provide animal grazing.

6.3.3.4 Size of Land Unit

There is no clear association between area of wheat held and complexity of rotation regime (Table 6.41). In the hills, however, a number of farmers commented that people with larger land-holding units may practice three rather than two course rotation regimes. This is not, however, borne out by the farmers practising three course rotation regimes in the hills and, in fact, proportionately more farmers used an 'intensive' cereal-legume rotation regime on the larger land units. The small size of units farmed by the study group, however, makes it difficult to assess the impact of scale on crop rotation regime.

6.3.3.5 Livestock

Both plains and hills villagers keep livestock, and crop rotation regimes are potentially affected by the need to supply fodder. Only 6 of the 26 farmers in the study group from the plains owned livestock whereas 32 out of 46 farmers owned animals in the hills with most (28) owning less than the equivalent of 3 FAO livestock units (Table 6.10). Most farmers owned less than 1 unit. Animal holding is greatest in the vegetation zones with evergreen trees (Fig. 6.17) and particularly, in the evergreen zone where the extensive forest cover provides grazing and browsing (although restrictions are placed on overuse). On the plains, many farmers commented that they had recently sold their animals due to lack of communal grazing areas (linked to the break-up of mushā'a tenure), insufficient labour to tend the flocks and widespread commercial availability of milk and milk products. Despite the apparent availability of grazing and browsing in the hills, farmers do complain that there is insufficient fodder available for their animals and partially blame government afforestation schemes and the fact that more of the forest is being taken into cultivation. Finding people to tend the flocks seems to be less of a problem in the hills, although a number of the farmers who had served in the army invested in cattle rather than goats or sheep because they were easier to herd.

Farmers often state that providing fodder for their animals is a perpetual problem. Contemporary fodder items grown by the farmers themselves are wheat chaff and straw, barley, lentil straw, and bitter vetch (straw and seed). Recently, *Vicia sativa* subsp. *sativa* has also been introduced. It might be expected that farmers with animals will insert a legume crop in their rotation regime and that farmers without livestock may eliminate legumes. All the farmers practising cereal-legume rotation own animals (Table 6. 42a). When the hills are considered alone, the results are even more striking (Fig. 6.18 and Table 6.42b) and most farmers who owned animals cultivated a legume in their cropping sequence. 77% of the farmers practising three year regimes (i.e. regimes including a legume) also owned animals. Only 3 out of 14 farmers who did not own animals used a winter legume in their crop rotation regime. All farmers with more than the equivalent of 3 FAO livestock units cultivated legumes in their rotation regime.

It has been observed that continuous cropping (of winter crops) is more commonly practised in areas with very high or very low rainfall (see 3.4). Shallow soils have the effect of reducing available moisture to the crop and therefore, are similar to cultivating under very low precipitation levels. As well as cultivated wheat, a few farmers cultivated small plots where the soils were very poor (often on sloping land). These plots were quite often cultivated every year - often with bitter vetch or barley - to provide fodder for animals. Most frequently, the crop was not harvested, but simply grazed. Under these conditions, farmers are less concerned with ensuring arable production than providing fodder for their animals and under these circumstances, any crop is better than none at all.

Of all the cultural factors analysed so far, ownership of animals has the greatest effect on the crop rotation regime used by farmers. This is particularly evident for farmers cultivating in the hills where the demand for fodder has caused changes in the traditional cereal-fallow regime - farmers are inserting a legume year. These results are supported by comments that some plains farmers are beginning to cut legume crops from their three year rotation regime as they no longer hold animals. Additionally, in border areas where the bedouin no longer graze their flocks on the stubble, some local farmers are no longer cultivating lentils as they cannot sell the straw to the pastoralists (E. esh-Shannag pers. comm.).

6.3.3.6 The Influence of Technology, Markets and Official Policy

The influence of mechanisation has already been discussed in 6.1. Mechanisation has filled labour shortfalls caused by off-farm employment. Jordanian farmers, however, have generally been slow to take-up many aspects of agricultural technology. The reasons are complex, but the following form the basis of most explanations: the small, fragmented and multi-owner nature of farm units, the shortage of machinery, the high cost of investment, and the fact that, for many households, agriculture is not the only source of income (el-Hurani 1988; 1989; Karablieh & Salem 1990; Mundy & Smith 1990). For the farmers in the study group, all these issues are important. Farmers also stress that investments (e.g. in fertilisers or improved wheat varieties) are unattractive due to the risks associated with variable rainfall. In addition, the government's pricing policy for wheat also contributes to farmers' reluctance to adopt new farming technology. Because of government control of wheat prices, but not input prices (cf. Qasem 1985, 397-99), households which supply most of their own wheat are unlikely to adopt new technologies, especially if they can buy subsidised wheat or wheat products (Aydin 1990, 199). The low price of wheat also affects what is planted during the fallow year - the choice of summer crop. As wheat can be bought comparatively cheaply, profitable crops which are 'hard' on the land such as tobacco may be used rather than a more 'restful' summer crop (or even bare fallow) which may be less detrimental to the following wheat yield.

The price that produce can attain on the market also influences farmers. This is particularly important in the choice of summer crops (see 6.2.1.2).

For mountainous regions in Jordan, cereal-legume rotation regimes are being promoted by agronomists (see 3.3.3). Cereal-legume regimes certainly seem to be being adopted by hills farmers, but the extent to which this is prompted by farmers themselves or agronomists is difficult to assess. In any case, their adoption certainly seems to be encouraged by animal ownership (see above).

6.3.4 Conclusions

Crop rotation regimes are primarily affected by precipitation. In the study area, sufficient precipitation is received to allow for complex rotations. Soil type - particularly depth and the capacity to store moisture - seems to go a long way towards explaining the dominance of two year crop rotation regimes in the hills and three year regimes on the plains.

Other cultural, or social, factors also affect the choice of crop rotation regime. The most striking association is between animal holding and regimes including a legume year. In the hills, for example, all the farmers practising a cereal-legume rotation regime and over three quarters of the farmers who practised a three year rotation regime owned animals. There is also some evidence for an association between labour availability and legume cultivation. Contemporary tenure also appears to affect rotation regime and there is a slight suggestion that continuous cropping is encouraged by renting. The change from communal land-holding to private ownership has allowed for more flexibility in crop rotation regime (and management generally), but has meant that animals have lost their grazing territory. As a consequence, many farmers, particularly on the plains, no longer keep animals. There are hints that this is just starting to affect the traditional three year rotation regime employed by plains farmers.

The persistence of cultivated fallow (which requires labour to till) in the study area has been partially facilitated by the adoption of tractor tillage which compensates for labour shortfalls and partly, by the growth of summer vegetable and fruit cultivation which are valuable at home and in the market. Fallow has become important for fruit and vegetable cultivation today as it was for winter animal grazing in the past. Farmers still advocate cultivated fallow as the best preparation for wheat.

6.4 'For My Children' - Long-term Strategies

6.4.1 The Long-Term Implications of Different Crop Rotation Regimes

So far, the value of cultivating different crops has largely been considered in terms of the value to the household of that crop (for human or animal consumption). Bare fallow has largely been considered as a technique which secures the next cereal crop. Over the long-term, however, different crop rotation regimes reflect and influence long-term trends in society. Long-term, the adoption of a particular regime also has an affect on overall productivity.

In terms of productivity, cereal-fallow (extensive) systems enable weeds to be controlled and, in the short-term, make nitrogen available to the crop from the breakdown of soil organic matter. In the long-term, low cutting of the crop and stubble grazing reduces organic matter and therefore, soil fertility and productivity is reduced. Harris (1991, 241) suggests that the traditional cereal-fallow rotation regime of the region represents a significantly depleted equilibrium (see 3.1.3). Under continuous cropping (intensive) systems, weeds are increased and can become a significant problem. Cereal-cereal and cereal-legume regimes have different effects on long-term productivity. Yields decline dramatically under continuous wheat cultivation and eventually, it is thought that the system will collapse (Chatterton & Chatterton 1986, 97). From Australian evidence, cereal-legume rotation, however, can potentially improve long-term fertility and even produce better total yields than cereal-fallow regimes (Buddenhagen 1990, 17; Chatterton & Chatterton 1984; 1986) and promote soil stability (see 3.2.3).

Today, depending upon particular social factors, farmers balance the medium- to long-term maintenance of the land with more immediate gain. Farmers who rent their land, however, tend to be particularly concerned with short-term gains (see 6.3.3.2). Farmers who own the land are more likely to fallow it, weed and manure it and generally, take care to insure long-term productivity so that, eventually, good land is passed on to their offspring. A number of older farmers commented that changes in crop management practices - less weeding, less manuring, and even the adoption of tractor tillage - were affecting crop quality and soil fertility. As less care is taken to weed, they say that crops are more often contaminated (often stated particularly in reference to straw quality) and yields are lower. Some farmers also blame tractor tillage for increasing soil erosion. It is often commented that because contemporary farmers usually have another source of income and not very much time, they are less concerned to invest in the land than in former times (at least, where the production of arable crops is concerned). Farmers also comment that more local people are renting out their land rather than cultivating it themselves.

As has been discussed in section 3.3.3, there are advantages to cereal-fallow rotation regimes which operate over and above considerations of productivity: it allows the spreading of the cultivation work-load and provides integrated grazing for livestock. The regimes used in northern Jordan under the communal land-holding system, balanced comparatively low productivity with stability (assuring the success of the crop) as well as maintaining a particular social system and 'equalising' the community. It balanced social and natural requirements. With the changes in society that have occurred this century, new forces (private land-holding, markets, lower provision of labour) are causing the pattern of arable farming to intensify (e.g. summer crops in the fallow year, the elimination of fallow). The other strategy is to abandon arable cultivation and grow trees.

6.4.2 The Investment in Trees - The Rise of the Olive Tree

There is a trend towards planting more tree crops, and particularly, olives. Planting trees is often expressed as a long-term investment bringing benefit to the following generation.

Tree cultivation has been encouraged in the study area by the government through the Highland Agricultural Development Project (financed by the World Food Programme). The main objective of the project has been to reduce soil erosion in the hilly areas by encouraging farmers to terrace land and plant trees rather than grow arable crops. Zarqa farmers have been offered incentives to participate in the project (Duwayri 1985, 127). In practice, it has also meant that farmers have been replacing oak forests with olive trees as well as planting trees on former arable land. Farmers on the plains have also been investing in olive trees even though many have commented that the plains soil is not suited to tree cultivation. This is because the large cracks that split open the soil in the summer months can be detrimental to the root systems of the trees.

Although government policy is certainly encouraging the increase in olive trees, it does not completely explain the whole phenomenon. When asked, farmers usually gave three reasons for planting trees. First, they explained that they yield good returns - 2 JD per litre of oil in 1991. Secondly, farmers emphasised that, once established, olives were easy to keep. Although regular tilling is necessary during the spring months to keep down weeds this could be achieved relatively cheaply and quickly with tractor tillage and family members can be called upon to pick fruits in the autumn evenings. The necessity for ease of farm management again reflects the high amount of off-farm employment - particularly amongst the younger generation. Olives are, therefore, a comparatively easy income supplement. Finally, it is important to stress that when arable land was held communally, prior to land registration, it would have been impossible for farmers to plant trees on good land as people changed the plots they were cultivating regularly.

It is in the area of olive cultivation that I most often found myself being asked for an opinion. According to agronomists, research has shown that many farmers in Jordan are unaware of the 'proper' care for olive trees. They are unaware, for example, of their root stocks, proper fertilisation, insect and pest control, and of the fundamentals of tree and vine pruning (al-Wir and Larsen 1981 in Duwayri 1985). This may illustrate just how much farming in the study area was arable based - except for the areas of established tree cultivation, of course. Equally, this may reflect the difference between 'traditional' and 'modern' management requirements. For example, many farmers complained about the new varieties of olive because they were more prone to disease than the local ones (and therefore, required expensive pesticides) and also required the correct (and once again expensive) fertilisers (i.e. not just manure). Farmers are more familiar with olive trees requiring relatively low levels of investment (cf. the badawīya - see 5.6).

6.5 Summary

In this chapter, the factors affecting crop management practices have been explored. The results can be summarised as follows:

1. The contemporary farmers interviewed - the study group - include 46 farmers from the hills and 26 from the plains. Most farmers were over 55 years old and half were life-long farmers (fellaheen). The average area of wheat cultivated was c.14 dunum, although farmers on the plains generally cultivated slightly larger areas than those in the hills. Equal numbers of hills farmers used animal tillage, but only 2 plains farmers used animal tillage.

2. This century, a number of profound changes has occurred in rural northern Jordan. Land registration gave local people the ability to manage their land on an individual or household basis, whereas previously many aspects of agricultural crop management - including choice of crop rotation regime - were controlled by a larger group (the village/tribal unit). Society has changed from being largely subsistence based to being increasingly cash orientated. Many people now work in off-farm employment which has resulted in a shortfall in agricultural labour (despite the huge population increases seen this century). Finally, mechanisation has helped to fill some of the labour

shortfalls, but has changed some of the roles played by men and women in crop management.

3. Short-term decisions made by farmers during the agricultural year are taken in response to events during the year (e.g. the onset of winter rains), but are affected by the needs of the household family and the amount of labour available to perform the various tasks. Contemporary farmers balance their actions according to what is needed to insure a reasonable yield. They are unwilling to make expensive investments in what they consider to be a risky enterprise - arable farming.

4. The choice of crop rotation regime used by farmers is greatly affected by precipitation and soil type. Most of the study area receives sufficient precipitation to allow for complex crop rotation regimes. Hills farmers, however, seem to be limited by their shallow soils which require more frequent fallowing to ensure yields. The choice of crop rotation regime, however, is also affected by factors which operate above and beyond these environmental constraints. There is a strong association between livestock ownership and legume cultivation, especially in the hills. The amount of labour available to harvest legumes also seems to affect whether legumes are cultivated. There is some evidence that renting encourages farmers to continuously cultivate the land. Market prices and government policies also influence farmers. The break-up of communal farming has facilitated increasing intensification of land use and year to year flexibility. It has also meant that the communal territory upon which local animals can be grazed has been dramatically reduced.

5. Farmers are increasingly investing in olive trees because of the good returns they bring and their ease of cultivation. Former arable land is being rapidly transformed into olive orchards and housing. Natural forest is also being replaced by cultivated trees.

6. Cultivated fallow has persisted in the study region, although today fallow with summer crops, rather than bare fallow, is dominant. Farmers continue to use cultivated fallow because, first they consider that it 'works', i.e. it rests the land and helps to ensure year to year production. Secondly, cultivating summer crops in the fallow year can provide valuable cash returns or make an important contribution to household consumption. Cultivated fallowing persisted in the past partially because it provided valuable animal grazing - today, it seems to persist partially because of the value of summer crops.

This chapter has been divided into three time scales: the short-, medium- and long-term. In the course of the discussion, however, the extent to which these time divisions grade into each other has become apparent. Most profoundly, the choice of crop rotation regime (a 'medium-term' strategy) has lasting implications for the maintenance of productivity and soil stability and reflects important long-term trends within society. Crop management practices, therefore, are indicators of long-term change. The way past crop management practices can be identified is the subject of the next chapter.

Chapter 7 The Ecological Effects of Crop Management Practices

'But while men slept, his enemy came and sowed tares among the wheat, and went his way'

Matthew 13: 25

This chapter sets out the results of the multivariate analysis of the botanical data and attempts to examine how - in particular - crop management practices affect weed composition. In the first section, patterns in the weed data are searched for using correspondence analysis (CA). Following this, the relationship between weed composition and all the external variables is explored using correspondence analysis (CA) with the external variables superimposed on the ordination diagram and canonical correspondence analysis (CCA) where the external variables are used to constrain the analysis of the weed data. The effect of crop management practices and vegetation zone on the weed data in particular are then examined using CCA. The stability of these CCAs are then investigated further by conducting a series of partial canonical correspondence analyses (PCCAs) where the effects of some of the external variables (the co-variables) are eliminated from the analyses (see section 4.4). Selected PCCAs are also repeated with reduced numbers of taxa.

In the final section, the association between different crop management practices and individual taxa is explored. In an attempt to understand how crop management affects the weed composition of a field, predictions are made on how weeds may be expected to behave under different crop management conditions and the actual behaviour of individual taxa in the analyses is examined. Following this, other taxa which may be responsive to different crop management practices are listed. Finally, a comparison is made between two of Zohary's phytosociological segetal associations for 'Western Palestine' and the weed flora of the hills and plains zones of the study area.

7.1 The Data

7.1.1 The Botanical Results

The taxa found in each field are listed in Appendix 7.1a and 7.1b - Appendix 7.1a is a list of the number of quadrats (out of 10) per field in which taxa were present at 'level 1' and Appendix 7.1b is a list of the number of quadrats (out of 10) per field in which taxa were present at 'level 2' (see section 4.3.2). Appendix 7.2a is a list of the taxa included in the following multivariate analyses, i.e. taxa present in three fields or more (for a full list of all the taxa and the taxa codes see Appendix 4.1).

7.1.2 The External Variables

In the exploration of the botanical data, the external variables used include the crop management variables and the 'environmental' variables (i.e. the farming background variables are not used - see chapter 6).

7.1.2.1 The 'Cultural' Variables - Crop Management Practices

The crop management practices associated with the sixty sampled fields are given in Appendix 7.3. This includes details of the fields' crop rotation regime, previous crop, tillage power used, sowing time, and how the fields were fertilised (also see Table 4.1a). All the crop management variables are nominal (see section 4.3.3.1). The two crop management variables that are examined in detail in this chapter are crop rotation regime and previous year's crop. In Table 7.1a and b, the numbers of fields sampled from each rotation regime and previous year's crop category in the hills and plains respectively are shown. All except two of the fields sampled on the plains were cultivated under a three year rotation regime. Fields sampled in the hills were largely cultivated under a two year rotation regime, but this includes both cereal-fallow and cereal-legume rotation regimes. No fields cultivated under a cereal-legume rotation regime were sampled from the plains. The usual cropping sequence for three year rotation regimes cultivated on the plains is: legume, fallow, and then cereal years. In the hills, the six of the nine fields cultivated under a three year rotation regime followed the cropping sequence: fallow, legume, and then cereal, i.e. a legume crop and not fallow preceded the wheat crop.

Due to the difficulty of locating non-typical crop rotation regimes and the limitation imposed as I was the only person sampling the fields for weeds, fewer fields from different crop rotation regimes were sampled than would have been ideal.

7.1.2.2 The 'Environmental' Variables

The 'environmental' details for the sixty sampled fields are given in Appendix 7.4. The nominal variables listed include the location of the fields in terms of the hills and the plains, the vegetation zone and the situation of the field in relation to position on the slope, degree of slope, and aspect. The quantitative variables include altitude, soil stoniness, crop height, and crop cover. The results of the soil tests are also given in Appendix 7.4 and are discussed briefly below.

7.1.2.2.1 Organic Content

The organic content of the sampled soil was low with a minimum value of 0.51% and a maximum value of 2.17%. These results are characteristic for Mediterranean soils which are typically low in organic content (see section 2.5). In general, soil organic content was higher in the hills (mean 1.27%) than on the plains (mean 0.85%).

7.1.2.2.2 pH

Soil pH ranged from 7.1 to 8.0 i.e. neutral to slightly alkaline soil. These values reflect the high amounts of calcium carbonate contained within the soils of the region. In general, soil pH was slightly higher on the plains (mean pH 7.72) than in the hills (mean pH 7.58).

7.1.2.2.3 Magnetic Susceptibility

The measurement of mass specific magnetic susceptibility was used in this study as an approximation for soil particle size (see section 4.2.5.3). The signals were very low (minimum value 0.050; maximum value 0.479) which indicates that there are insufficient magnetic minerals in the soils to enable distinctions to be drawn (S. O'Hara pers. comm.).

7.2 Examining the Differences in Weed Flora

7.2.1 Analysis of All Fields

7.2.1.1 'Pattern-searching' using Correspondence Analysis

The first stage in the analysis was to ascertain if there were any determinable 'patterns', or 'gradients', in the weed flora. This was done by conducting a simple correspondence analysis of the 'level 1' weed taxa alone. In the resulting ordination diagram (Fig. 7.1), the first axis clearly separates fields on the plains from those in the hills (all the vegetation zones with trees are located in the hills). In addition, the analysis seems to put the three fields which had been previously left as weedy fallow at one end of axis I (Fig. 7.2). Axis I also tends to separate fields cultivated under a 3 year crop rotation regime from the other fields and especially those cultivated under a cereal-legume rotation regime. This separation between cereal-legume and other regimes is important because in particular, cereal-legume and cereal-fallow regimes were both sampled in the hills - therefore suggesting that crop rotation regime may be affecting weed composition. There is no clear separation of fields with different crops grown in the previous year, although fields with winter legumes as the previous crop are mostly situated to the left of the diagram (Fig. 7.3).

Axis II separates the different types of vegetation zone located in the hills with evergreen and degraded evergreen zones at one end and deciduous zones (either mixed or degraded deciduous zones) at the other (Fig. 7.1). The evergreen and degraded evergreen zones are located at the highest altitudes in the study area - the evergreen oak, *Q. calliprinos*, is most commonly found above the 700 mm contour (al-Eisawi 1985, 53). The degraded deciduous zone is situated at lower altitudes - the deciduous oak, *Q. ithaburensis*, occurs typically between 300 and 600 m (Feinbrun and M. Zohary 1955, 19). Axis II, therefore, appears to be broadly separating fields on the basis of altitude. Furthermore, fields 17, 18, 21, 23, 36, 55, and 56, which are all positioned at the extreme 'evergreen' end of axis II, were located at the highest altitudes in the study area. Fields from the mixed zone, however, are positioned at the other extreme of axis II, although these fields were not located at the lowest altitudes. Fields in the degraded deciduous zone (and in the plains) were located at the lowest altitudes of the study area. No clear patterns were observed along the third or fourth axes of the CA.

The summary of the CA of all the fields is given in Table 7.2. The eigenvalues are a measure of how much of the variation in weed composition is accounted for by each axis. The eigenvalue for the first axis of the CA is typical for ecological applications, i.e. approximately 0.3 and higher (ter Braak 1988, 39). The cumulative percentage variance of the weed data is low, but ter Braak comments that even an ordination that explains only a low percentage of the weed composition may be quite informative (ter Braak 1986, 1172). As the first axis accounts for most of the variation in weed composition, either the difference between the hills and plains zones or between two and three year crop rotation regimes appears to explain most of the observed variation.

There are five fields which were not managed using either a two or three year crop rotation regime. As noted above, the three fields which had previously been left as weedy fallow are situated to one extreme of axis I. It is probable that some of the differentiation between two and three year crop rotation regimes was slightly obscured by the inclusion of these fields in the analysis and therefore, these fields were eliminated from the data matrix in further analyses. The two other fields managed under unusual regimes include one field which had previously been cultivated with wheat (40) and one which had been cultivated with summer crops for ten years (22). It is interesting that field 22 is situated at one of the highest altitudes in the study area (directly adjacent to field 21) and in the hills but, in Fig. 7.1, it is located more towards the group of fields sampled in the plains and well away from fields which were located at a similar altitude. It is likely, therefore, that the weed composition of this field was affected by its cropping history but because only one field managed in this way was sampled, it is difficult to draw any definite conclusions. This field was, therefore, removed from subsequent analyses. Although field 40 does not appear to be distorting the observed 'patterns', it was also removed from subsequent analyses because it is also a single example of an unusual cropping history.

The general 'patterns' discussed above were obtained from the analysis of the 'level 1' data set. When the analysis was repeated using the 'level 2' data set, very similar ordination diagrams were produced except that field 6 was exposed as an extreme outlier. In the 'level 1' analysis, this field emerged as an outlier on axis IV. During the interview for field 6, there was some doubt raised as to whether it had been treated with weed-killers. Its behaviour in the analyses suggests that this may indeed be true. Consequently, this field was removed from subsequent analyses. In total, this means that six fields were eliminated. This also meant that some of the taxa were also removed (only taxa included in three fields or more were included in the analyses). This reduced the number of taxa included from 108 to 100 in the 'level 1' analyses and from 109 to 101 in the 'level 2' analyses (see Appendix 7.2b).

A CA of the fields cultivated under two and three year crop rotation regimes alone (i.e. without fields 6, 19, 20, 22, 25 and 40) gave similar results to the analysis using all the fields (Figs. 7.4, 7.5, 7.6 and Table 7.3). Hereafter, all analyses were conducted using this data set and future analyses using fields cultivated under two and three year crop rotation regimes from both the hills and plains zones will be referred to as 'all the fields'.

7.2.1.2 Relationship between Weed Flora and the External Variables - Canonical Correspondence Analysis

The next stage in the analysis is to incorporate the external variables. This was performed in two ways: first, by superimposing the external variables on the ordination diagram produced by the unconstrained correspondence analysis (CA) and secondly, by conducting a canonical correspondence analysis (CCA) where the external variables are used to constrain the ordination based on the weed taxa (see section 4.4). The results of the CA and CCA were very similar, and therefore, only the CCA is described here. As the results of the CA and CCA were similar, it follows that the observed external variables largely account for the variation in weed composition (ter Braak 1986, 1177).

The influence of a particular external variable on weed composition can be assessed by its position in the ordination diagram. In the case of quantitative variables (represented by lines radiating from the origin of the diagram), the length of the line is a measure of how much influence that variable has on the ordination. Therefore, more important quantitative variables tend to be represented by longer lines than less important ones (ter Braak 1986, 1172). Nominal variables are represented by points in the ordination diagram rather than lines. The point for a category of a nominal variable is located at the centroid (the weighted average) of the fields belonging to that category (ter Braak 1986, 1172).

First, all the external variables (Appendix 7.3 and 7.4) were included in the CCA. This meant, however, that there were too many variables to be plotted by the drawing package CANODRAW. In order to plot the external variables, therefore, the following external variables were omitted: the position of a field on a slope, degree of slope, and the field's aspect. These variables were excluded because they were very closely related to the location of a field. For example, all the fields on the plains were on flat land, were classified 'basin bottom' (the plains are at the base of the hills and most of the soils are alluvially derived), and had an undifferentiated aspect. Fields in the hills, on the other hand, were usually on sloping land and therefore, had different aspects and different positions on the slope. The validity of eliminating these variables can be measured by examining the eigenvalues and taxa-external correlations of the analyses before and after their removal - if the values are similar, the removal of the variables is justified (ter Braak 1986, 1171).

All the analyses were conducted using the 'level 1' and 'level 2' data sets. In addition, the analyses were rerun using the 'level 1' data set excluding the ten most common taxa in an attempt to increase the significance of detected patterns (N. Fieller pers. comm.). As there are a comparatively large number of taxa compared to the number of fields, reducing the number of taxa should increase the significance of underlying patterns, especially crop management practices (the problem of the large number of taxa will also be explored further in 7.4.2). (The ten most common taxa and their number of occurrences are listed in Appendix 7.5.) In the event, there was very little difference between the three sets of analyses. The following discussions, therefore, refer to the results of the 'level 1' analyses (including the common taxa).

The results of the canonical correspondence analysis (CCA) with all the external variables (excluding position on the slope, degree of slope, and aspect) are shown in Figs. 7.7-7.10. Fig. 7.7 shows the position of the external variables on the axes without the fields. Figs. 7.8, 7.9 and 7.10 show the position of the fields coded according to background vegetation, crop rotation regime, and previous year's crop respectively. The summaries of the CCA with all the external variables and the CCA excluding the variables position on the slope, degree of slope and aspect are given in Tables 7.4a and 7.4b. As there is only a small difference between the sum of all the canonical eigenvalues and the sum of all the constrained eigenvalues for the two analyses then the elimination of the variables position on the slope, degree of slope and aspect would seem to be justified.

The hills category is situated to one side of axis I and the plains category to the other in the plot of the CCA showing the position of the external variables alone (Fig. 7.7). This is also very clear in Fig. 7.8 where fields in the hills vegetation zones are at one end of axis I and fields in the plains vegetation zone at the other. Axis I also separates three year rotation regimes from two year rotation regimes (Figs. 7.7 and 7.9) and, partially, other crops from legume crops as the previous years crop (Fig. 7.7 and 7.10). Axis II is strongly associated with altitude (Fig. 7.7). Fields in the evergreen vegetation zones are situated at one end of axis II and fields in the deciduous zones at the other (Fig. 7.8). All these trends were apparent from the CA (Figs. 7.4-7.6). In the CCA, the clustering of fields into different vegetation zones is largely the same as in the CA (compare Fig. 7.8 with Fig. 7.4). The distribution of fields cultivated under different rotation regimes is also very similar (compare Fig. 7.9 with Fig. 7.5). The distribution of fields in relation to their previous crop is also similar, although most fields previously cultivated with a legume crop are 'pulled' very slightly to the left from their original position in the CA (compare Fig. 7.10 with Fig. 7.6).

In the plots of the CCA, it is possible to assess the association between external variables. Situated with the plains, towards the end of axis I, are the plains vegetation zone, three year rotation regimes, and high pH levels (Fig. 7.7). Also positioned slightly towards this end of axis I are the variables: tillage by tractor, previous cultivation with summer crops, no weeding, high sowing rates (although this is strongly associated to axis II - see below), fertilisation of the fields by grazing, sowing after the rains, and higher magnetic susceptibility values. Associated with the hills zone at the other end of axis I are: high organic content, high soil stoniness, the cereal-legume rotation regime, the cereal-fallow rotation regime, a legume crop in the previous year, animal tillage, and the vegetation zones with trees. At the end of axis II, which is associated with high altitude, are the evergreen vegetation zones and sowing before the rains. The previous application of bare fallow is also associated with this end of axis II. Situated with the deciduous vegetation zones at the other end of axis II (and not detected from the CA) are high crop height, dense crop cover, tillage by animal, and weeding. As both crop height and crop cover affect the amount of light available, their association suggests that shade affects weed composition along axis II. High crop cover and high sowing rates are also positioned close to each other suggesting that higher sowing rates are related to a denser crop cover. There is an interesting association between manuring, a preceding legume crop, and high soil organic content and their association may reflect high levels of soil fertility. No variables were strongly associated with the third and fourth axes.

7.2.1.3 Conclusions

As the distribution of fields in the CA and CCA ordination diagrams is very similar, the recorded variables largely account for the variation in weed composition. There are a number of important associations between the variables. For example, stoniness and high organic content are associated with the hills zone and two course rotation regimes; three course rotation regimes and high pH with the plains zone; high altitude with the evergreen vegetation zones; and crop cover and crop height with medium altitudes (the deciduous vegetation zones). Vegetation zone and/or crop rotation regime appear to explain most of the variation in weed composition - at this stage in the analysis, however, the extent to which each of these variables contribute to that variation has not been established.

7.2.2 Analysis of the Hills Fields

In order to eliminate the strong effects of location in the hills or plains and explore the differences which are due to crop rotation regime, the CA and CCA with all the external variables were repeated using the fields in the hills alone. In this way, it should be possible to decide whether axis I is simply due to the dichotomy between the hills and the plains, or if it is more interestingly due (at least partly) to differences in rotation regime. (It was not appropriate to conduct the same analysis for the plains alone because all except two of the fields were cultivated under the a three year rotation regime.) The number of fields analysed was reduced to 36 and the number of taxa found in three or more fields to 91 in the 'level 1' and 'level 2' analyses and 81 in the 'level 1' analyses where the ten most common taxa were removed (see Appendix 7.2c).

7.2.2.1 'Pattern-searching' using Correspondence Analysis

When all the fields from the plains are removed from the CA, the function of separating the hills fields according to their vegetation zone is taken over by axis I (instead of axis II in the analysis using all the fields) and consequently, evergreen vegetation zones are at one end of axis I and deciduous zones at the other (Fig. 7.11). There is no clear separation of fields according to their rotation regime or previous year's crop on either axis I or axis II (Fig. 7.12 and Fig. 7.13, but there is a partial separation of fields which had been previously bare fallowed from those previously cultivated with a winter legume on axis III (Fig. 7.14). This is potentially interesting because there is a relatively even spread within the evergreen vegetation zones of fields previously cultivated with bare fallow and winter legume crops - five and seven fields respectively. In the deciduous zones, four fields had previously been cultivated with a legume crop and only one previously cultivated with bare fallow. Fields cultivated using a cereal-legume rotation regime are concentrated at one end of axis III, but these fields are not separated from fields cultivated under either a cereal-fallow or a three year crop rotation regime (Fig. 7.15). Three fields from the deciduous vegetation zone and four fields from the evergreen vegetation zones were cultivated using a cereal-legume rotation regime. For details of the crop rotation regimes and previous year's crops of fields in the hills vegetation zones see Table 7.5a and 7.5b.

The summary of the CA of the hills fields is presented in Table 7.6. The total inertia for the CA of the hills fields is somewhat lower than in the CA of all fields (see Table 7.2) which reflects the greater similarity in weed composition of fields in the hills. This greater similarity is also probably responsible for the lower eigenvalue of axis I (0.34 compared to 0.26). The first axis, which separates fields according to their location in the different vegetation zones of the hills zone, accounts for most of the variation in weed composition.

7.2.2.2 Relationship between Weed Flora and the External Variables - Canonical Correspondence Analysis

The CA of the hills fields was repeated with the external variables superimposed on the ordination diagram. This analysis produced very similar results to a CCA where the external variables were used to constrain the ordination (as was the case with the same analyses including all the fields) and therefore, only the results of the CCA will be described here. The similarity between the CA and CCA of the hills fields once again suggests that the external variables largely explain the variation in weed composition (also see section 7.2.2).

The CCA was conducted once with all the external variables and once without the variables position on the slope, degree of slope, and aspect (the ordination diagrams use the results from the latter CCA). Where all the external variables were included, there were more variables than fields. When the number of external variables exceed the number of fields, there is a problem of multicollinearity which means that the effects of particular variables on weed composition cannot be separated out (ter Braak 1986, 1170-1). Even after the variables position on the slope, degree of slope, and aspect have been removed, there are nearly as many external variables as fields so that some caution is required when the results are interpreted. In addition, removing the plains fields from the analyses, reduced the number of fields by 18, but only reduced the number of taxa by 10, i.e. the number of taxa is almost three times the number of fields.

The summaries of the CCAs of the hills fields are shown in Tables 7.7a and 7.7b. The eigenvalues for axis I are slightly lower than in the CA (Table 7.6) and notably lower than the CCA with the hills and the plains together (Table 7.4a and 7.4b) which again suggests that there is less variation in weed composition in the hills fields alone. There is a drop in the sum of the canonical eigenvalues between the CCA with all the external variables and the CCA without the variables position on the slope, degree of slope and aspect, but it is not very large - thus suggesting that the elimination of these variables is justified.

In the CCA of the hills fields, altitude is strongly related to axis I (Fig. 7.16) which also separates evergreen and deciduous vegetation zones (Fig. 7.17) - as was evident from the CA (cf. Fig. 7.11). The position of the fields on the ordination diagrams shift slightly between the CA and CCA, but the overall grouping into evergreen and deciduous vegetation zones is very similar. Crop cover, soil stoniness, weeding and crop height are also related to axis I (and also associated with fields from the deciduous forest zone) (Fig. 7.16). Axis II appears to be related to high organic content, high pH and manuring. No patterning of fields, according to rotation regime or the previous year's crop, was observable on axis I or II (Fig. 7.18 and Fig. 7.19). On axis III, there is again, as was noted in the CA, a partial separation of fields according their previous year's crop with fields previously cultivated with a legume crop at one end of the axis and, except for one field, bare fallow at the other (Fig. 7.20). Compared to the CA (Fig. 7.15), the position of some of the fields shifts slightly - notably one field which had previously been bare fallowed is positioned firmly with the fields which had previously been cultivated with a legume crop. Most of the fields which had previously been bare fallowed, however, have moved further to the other end of axis III. One field which had previously been cultivated with a legume crop has moved 'up' with the fields which had previously been bare fallowed. The fields which were cultivated under a cereal-legume crop rotation regime are, excluding the one field which has moved further up axis III, remain concentrated, but not isolated, at one end of axis III (Fig. 7.21). Fields which had been cultivated under a three year crop rotation regime which had a legume crop rather than fallow (either bare fallow or fallow with summer crops) in the previous year of cultivation, are situated at the end of axis III associated with cereal-legume cultivation. Other variables which are important on axis III are high organic content and manuring (and also stoniness) (Fig. 7.22). Alongside the observation that legume as a previous crop and cereal-legume rotation are also associated with axis III, this suggests that the third axis represents soil fertility.

7.2.2.3 Conclusions

Comparison of the CA and CCA of the hills fields alone reaffirms the earlier observation that the recorded external variables account well for the variation in weed composition. Altitude and/or vegetation zone appear to be the variables that account for most of the variation, with stoniness, high soil organic content as well as crop height and crop cover associated with fields from the deciduous zone. Most importantly, however, crop management does appear to have an impact on weed composition and an interesting separation is visible between fields under legume rotation and those previously bare fallowed. The cultivation of a legume crop in the previous year is also associated with manuring and with high soil organic content.

7.3 Exploring the Effects of Particular External Variables on Weed Flora

7.3.1 Canonical Correspondence Analysis of All Fields

The next stage in the analysis was to investigate the effect of particular variables on weed composition. A series of CCAs were, therefore, conducted using particular external variables to constrain the ordination. First, the variables crop rotation regime and previous year's crop - the crop management variables which are the subject of this investigation - were used to constrain the ordination. Secondly, vegetation zone which has already been shown to have a major effect on weed composition, was used to constrain the ordination.

54 fields and 99 taxa (for the 'level 1' analyses) are included in the following analyses (as in section 7.3.1). It is important to note that when there are more taxa included in a CCA than cases (fields), there is an increased possibility of detecting differences in weed composition which are due to chance rather than the influence of a particular variable. This fact may be reflected in reduced significance of the analyses. On the other hand, and for the same reasons, it may also be difficult to establish a significant result for small differences in weed composition which are genuinely caused by the influence of a particular variable.

7.3.1.1 Crop Rotation Regime

The effects of rotation regime on weed composition were explored in three ways. First, the effect of the three main regimes - cereal-legume, cereal-fallow and three year rotation regimes (i.e. 3 categories) were investigated and secondly, the effect of two year and three year rotation regimes (i.e. 2 categories) was contrasted. Finally, the effect of the cereal-legume rotation regime and regimes including a fallow year was contrasted (i.e. 2 categories again). The summary results of these CCAs are given in Table 7.8.

In the first CCA, using crop rotation regime with three categories (cereal-legume, cereal-fallow and three year rotation regimes) to constrain the ordination, there is a very good separation of the categories (Fig. 7.23). Axis I partially separates three year rotation regimes from two year regimes and axis II separates cereal-fallow from cereal-legume regimes. Of the seven fields which were cultivated under a three year crop rotation regime in the hills, five are situated with cereal-fallow rotation regimes thus suggesting that, in these cases, location in the hills has a more profound effect on weed composition than crop rotation regime. The two fields which were cultivated under a cereal-fallow rotation regime on the plains are situated with the other cereal-fallow fields. There is a good separation of fields which were cultivated under cereal-legume and cereal-fallow regimes and, as fields from both regimes were sampled in the hills zone, this suggests that this separation is due to crop management rather than vegetation zone. A Monte Carlo permutation test (see section 4.4) showed the results to be significant ($p \leq 0.01$).

To compare the effects of two year crop rotation regimes and three year regimes on weed composition, cereal-legume and cereal-fallow rotation regimes were treated together and the CCA rerun. Fig. 7.24 is the resulting ordination diagram and there is a good separation of two and three year regimes primarily on axis I (and, to a lesser extent on axis II). There is, however, an area of overlap between the two groups - fields cultivated under a three year crop rotation regime in the hills are situated towards the end of axis I which is associated with two year rotation regimes. This suggests that location in the hills and plains is causing most of the variation in weed composition. The result, however, is significant ($p = 0.02$).

Finally, to contrast the effects of cereal-legume rotation regimes and regimes including a fallow year on weed composition, cereal-fallow rotation regimes and three year rotation regimes were treated together and the CCA rerun. In the ordination diagram, the six fields cultivated under a cereal-legume rotation regime are situated at one end of axis I (Fig. 7.25). The result is significant ($p = 0.02$).

7.3.1.2 Previous Year's Crop

The effect of the previous year's crop on weed composition was analysed next by using the variable previous year's crop to constrain the ordination. This was conducted in two ways, first, the effect of bare fallow, fallow with summer crops, and winter legumes in the previous year (i.e. 3 categories) on weed composition was examined and secondly, the effect of fallow and winter legume crops (i.e. 2 categories) was contrasted. The summary results of these CCAs are given in Table 7.8.

In the CCA using previous year's crop with three categories to constrain the ordination, there is a reasonably good separation between the categories with legume crops in the previous year at one end of axis I and a preceding fallow year (bare fallow and fallow with summer crops) at the other (Fig. 7.26). With the exception of one field, bare fallow is situated to one end of axis II and fallow with summer crops at the other. The result is just significant ($p = 0.05$). The reduced significance is probably partially the result of the low numbers of fields in the winter legume and bare fallow categories (N. Fieller pers. comm.). It would seem, however, that the influence of crop rotation regime on weed composition is stronger than the effect of the previous year's crop.

To compare the effect of a previous winter legume crop and a preceding fallow year on weed composition, bare fallow and fallow with summer crops were treated together and the CCA repeated. In the resulting ordination diagram, fields which had a legume crop in the previous year are situated towards one end of axis I, although one field (importantly, the only field in the plains with a legume crop in the previous year) overlaps with the fields at the other end of axis I which had been fallowed in the previous year (Fig. 7.27). The result is significant ($p = 0.02$). This is the same significance as when cereal-legume rotation and regimes including a fallow year are contrasted.

7.3.1.3 Vegetation Zone

In the CCA examining the effect of vegetation zone on weed composition there is an extremely good separation of the different zones (Fig. 7.28). The plains vegetation zone lies to one end of axis I whereas the forested zones (found in the hills) are situated at the other end. For the forested zones, there is a division along axis II between evergreen and deciduous vegetation zones. This result is significant ($p \leq 0.01$).

The eigenvalues and taxa-external correlations for axes I and II and the sum of the canonical eigenvalues where vegetation zone is the constraining variable are the highest of the variables analysed (Table 7.8). This and the clearer separation of the vegetation zones in the ordination diagrams, suggests that location in the vegetation zones accounts for more of the variation in weed composition than crop management. It should be noted, however, that the statistical significance of the eigenvalues and taxa-external correlations is not fully understood (ter Braak 1986, 1177). Therefore, comparison between the eigenvalues and taxa-external correlations is not entirely straightforward, especially as the figures also appear to be affected by the number of constraining variables.

7.3.1.4 Conclusions

From the above analyses, it is evident first, that vegetation zone has a more important effect on weed composition than crop management (apparent from the plots, eigenvalues and the taxa-external correlations). Secondly, crop rotation regime appears to have a more important effect than the previous year's crop but as the former is strongly correlated with vegetation zone, this may be an indirect reflection of that. The separation of cereal-fallow and cereal-legume rotation regimes - regimes which are both associated with the hills zone - suggests, however, that crop management regimes do indeed have an effect on weed composition. There was also a reasonably good separation of fields according to their previous crop but this may, once again, be an indirect reflection of the concentration of fields previously cultivated with a legume crop or bare fallow in the hills zone.

In order to eliminate the strong effect of location in the hills and plains and explore differences in weed composition which may be due to crop management, the CCAs using particular external variables were repeated using the hills fields alone.

7.3.2 Canonical Correspondence Analysis of the Hills Fields

The effect of crop rotation regime, the previous year's crop and vegetation zone on weed composition was also investigated for the 36 fields sampled in the hills. This was conducted using exactly the same series of CCAs as was used in the analysis of all the fields. First, the variables crop rotation regime and previous year's crop - the crop management variables which are the subject of this investigation - were used to constrain the ordination. Secondly, vegetation zone was used to constrain the ordination.

There are 91 taxa included in the 'level 1' and 'level 2' analyses - over twice as many taxa as fields - in the analyses of the hills fields. As noted previously, when the number of taxa exceeds the number of fields in a CCA, it is easier to obtain differences in weed composition which may be due to chance rather than the influence of a particular variable. As there are more than twice as many taxa as fields, the possibility of obtaining patterns which are due to chance is further increased in the CCA of the hills fields. The eigenvalues and taxa-external correlations for the first two axes plus the sum of the canonical eigenvalues for the following CCAs are shown in Table 7.9.

7.3.2.1 Crop Rotation Regime

As with the analysis of hills and plains fields together, the effect of crop rotation regime on weed composition was analysed in three ways. First, the effect of the three rotation regimes (cereal-legume, cereal-fallow and three year rotation regimes) were explored, secondly, the effect of two and three year rotation regimes was contrasted, and finally, the effect of cereal-legume and rotation regimes including fallow were investigated.

In the CCA using three categories, cereal-legume, cereal-fallow and three year rotation regimes, there is a dramatic improvement in the separation of the three categories (Fig. 7.29) compared to the CA (Fig. 7.12). The result, however, is not significant ($p = 0.82$). The improved separation in the ordination diagram may, therefore, be due to chance factors. As noted above, the number of taxa used in the analysis greatly exceeds the number of fields and in such cases, there is an increased possibility of finding patterns in the ordination which may be due to chance rather than the influence of a particular variable.

When the fields were coded according to whether they were cultivated under a two or three year regime and the CCA rerun, the separation of the two regimes is reasonably good (Fig. 7.30) but again not significant ($p = 0.83$).

Finally, in the CCA contrasting the effect of cereal-legume rotation and regimes including a fallow year, there is a good separation of the two regimes (Fig. 7.31). Once again the result is not significant but the result of the Monte Carlo permutation test ($p = 0.49$) is the best of the three CCAs using crop rotation regime as the constraining variable.

7.3.2.2 Previous Year's Crop

The effect of previous year's crop on weed composition was also examined using the variable previous year's crop to constrain the ordination. This was again conducted in two ways: first, the effects of the three alternative previous crops categories were examined and secondly, the effects of a previous fallow year or winter legume year were contrasted.

There is a very good separation of fields previously cultivated with a winter legume, bare fallow with summer crops and bare fallow in the CCA of the hills fields (Fig. 7.32) which is dramatically different to the CA (Fig. 7.13). The result, however, is not significant ($p = 0.37$).

When the analysis was rerun with the fields coded as two categories (winter legume and fallow), there is again a good separation of the two categories (Fig. 7.33). Once again, however, the result is not significant ($p = 0.44$).

In the hills, the significance of the CCAs which used previous crop as the constraining variable are generally greater than the CCAs using crop rotation regime to constrain the ordination (the difference is very pronounced in the CCAs using three categories and the two and three year rotation regime categories). This suggests that the previous crop has a more detectable effect on weed composition than longer term crop rotation regimes. The result of a Monte Carlo permutation test for the CCA contrasting the cereal-legume rotation regime and regimes including a fallow year, however, was closer to the result of the CCAs using previous year's crop as the constraining variable. The improved significance of the CCA contrasting the cereal-legume rotation regime and regimes including a fallow year may be an indirect result of the fact that these fields were previously cultivated with a legume crop rather than reflect the effect on weed composition of a long term cropping pattern. From the CA of the hills fields (compare Fig. 7.12 and Fig. 7.13) and CCAs of the hills fields using particular variables to constrain the ordination, it would appear that short term crop management (i.e. the previous year's crop) has a more profound effect on weed composition than long term crop rotation regimes. A legume as the previous year's crop and legume crop rotation regimes are not related to particular hills vegetation zones (see Table 7.5a & b) and so this effect cannot be an indirect reflection of vegetation zone.

7.3.2.3 Vegetation Zone

The final CCA conducted with the hills fields alone, investigated the effect of vegetation zone on weed composition. There is a very good separation, along axis I, between the degraded evergreen and evergreen forest zones on the one hand and the forest zones with a deciduous component on the other (Fig. 7.34). There is, in addition, a good separation, along axis II, between the degraded deciduous forest zone and the 'mixed' forest zone. The result is significant ($p \leq 0.01$). Vegetation zone, therefore, accounts best for the variation in weed composition.

The eigenvalues and taxa-external correlations for all the CCAs conducted using the hills fields alone are shown in Table 7.9. Comparison of the eigenvalues of axis I and II confirms that vegetation zone accounts for most of the variation in weed composition (although, as noted above, some caution is necessary when making these comparisons). The taxa-external correlations are also the best for vegetation zone.

7.3.2.4 Conclusions

For the hills fields, vegetation zone has a more important effect on weed composition than crop management. Comparison of the CA and CCAs and the lack of significance of the CCAs where crop management variables were used to constrain the analyses suggest that such differences as have been observed in the analyses may be due to chance differences in weed composition between the fields. This is often the case when the number of variables (in this case taxa) exceeds the number of cases (in this case fields) (N. Fieller pers. comm.). Although vegetation zone remains the most important factor governing weed composition, there is a hint from the ordination diagrams that crop management may have an effect on weed composition and that the previous year's crop (short-term crop management) may have a slightly greater effect on weed composition than rotation regime (middle- to long-term crop management). Overall, however, and in this investigation, the large number of taxa compared to fields may, in fact, make it difficult to establish a significant result for small differences in weed composition due to crop management.

7.4 Isolating the Effects of Crop Management Practices - Partial Canonical Correspondence Analysis

7.4.1 Using All Taxa

In order to investigate the effects of crop management on weed composition apart from the effects of other external variables, a series of partial canonical correspondence analyses (PCCAs) were conducted. In these analyses, the ordination is based on weed composition constrained by the crop management variables (rotation regime and previous year's crop taken independently) whilst the effects of other external variables (the co-variables) are eliminated. The analyses were repeated using four different sets of co-variables. First, the effect of vegetation zone only was eliminated because this is the most important factor determining weed composition. Because vegetation zone and crop rotation regime are correlated (i.e. three year rotation regimes are associated with the plains fields and two year regimes with the hills fields), eliminating the effect of vegetation zone may also eliminate some of the effects of crop rotation regime on weed composition. Secondly, the effect of vegetation zone, altitude, soil stoniness, soil pH, and soil organic content (five co-variables) were eliminated. These last four variables were important factors in the CCA with all the external variables (see Fig. 7.7 where these variables have the longest lines on the ordination diagram). Next, the effects of these last five co-variables plus crop height and crop cover were eliminated - they also appeared as important factors in the CCA with all the external variables (Fig. 7.7). It should be noted, however, that crop cover and height may be factors which are responding to different crop management practices. Finally, all the external variables, other than crop rotation regime and the previous year's crop, were eliminated. (The hills and plains variable was not eliminated because this duplicates the variation accounted for by vegetation zone.) If the separation of the different crop management categories remains stable in the PCCAs, then crop management does indeed have an effect on weed composition which is independent of other variables.

7.4.1.1 Crop Rotation Regime

The PCCAs conducted in order to isolate the effects of crop rotation regime are listed in Tables 7.10, 7.11, and 7.12. The figure numbers and the significance of the Monte Carlo permutation tests are also given.

In the PCCAs conducted with the three categories of rotation regime (cereal-legume, cereal-fallow and three year rotation regimes) constraining the ordination, the separation of the three categories is less clear than in the CCA with no constraining co-variables (cf. Fig. 7.9). Where vegetation zone is the only co-variable, there is still a reasonable separation of cereal-legume rotation regimes and the regimes including a fallow year, but some overlap between cereal-fallow and three year crop rotation regimes exists (Fig. 7.35). When the effects of the five co-variables are eliminated from the analysis there is more overlap between cereal-fallow and three year rotation regimes (Fig. 7.36). In the final two PCCAs, where the five co-variables plus crop height and crop cover were eliminated and then all the other external variables, the separation of the three rotation regimes is obscured although the patterning does not disappear entirely (plots not shown). None of the PCCAs is significant (in the CCA, the analysis was significant: $p \leq 0.01$).

The separation of two and three year crop rotation regimes is also less clear in the PCCAs compared to the corresponding CCA (cf. Fig. 7.24). The separation of the two categories, worsens between the PCCAs when the effects of vegetation zone (Fig. 7.37) and five co-variables are eliminated (Fig. 7.38). There is only a limited difference between the plots when five, seven or all the other external co-variables are eliminated (the latter two plots are not shown). None of the analyses is significant (Table 7.11) (in the CCA, the analysis was significant: $p = 0.02$).

The separation between cereal-legume rotation and rotation regimes including a fallow year is less clear in the PCCAs compared to the corresponding CCA (cf. Fig. 7.25). Once again, the separation of the two categories, worsens between the PCCAs when the effects of vegetation zone (Fig. 7.39) and five co-variables were eliminated (Fig. 7.40). There is only a limited difference between the plots when five, seven or all the other external co-variables are eliminated (the latter two plots are not shown). The PCCAs are not significant (Table 7.12) (the CCA was significant: $p = 0.02$).

None of the results of the PCCAs is significant suggesting that once the effects of vegetation zone have been eliminated, the remaining variation in weed composition between rotation regimes may be due to chance.

7.4.1.2 Previous Year's Crop

The same PCCAs were conducted with the previous year's crop as the constraining variable. Tables 7.13 and 7.14 give details of these analyses as well as the figure numbers and the significance of the Monte Carlo permutation tests.

The separation of fields in the PCCAs with a legume crop, bare fallow and fallow with summer crops as the previous crop is much clearer than that for rotation regimes. Indeed, when vegetation zone alone (Fig. 7.41) or the main five external variables (Fig. 7.42) are used as co-variables, the separation of fields according to their previous crop is similar to that of the corresponding CCA (with no co-variables) (cf. Fig. 7.26). The separation of fields which had been bare fallowed as opposed to fields which had previously been cultivated with a legume crop is particularly clear. The PCCAs using seven or all the other external variables were slightly less clear (plots not shown). The results of these analyses, however, are not significant (Table 7.13) (the CCA was nearly significant: $p = 0.08$). Once again, this suggests that the variation in weed composition due to the previous crop may also be due to chance.

In the PCCAs contrasting fallow and a legume as the previous crops (Table 7.14), the separation of the two categories is almost as clear as in the corresponding CCA (Fig. 7.27) when vegetation zone (Fig. 7.43) or the five main external variables (Fig. 7. 44) are used as co-variables but less clear when seven or all the other external co-variables are used (plots not shown). The results are again not significant (although the CCA was significant: p = 0.02).

7.4.1.3 Vegetation Zone

In order to determine whether the observed differences in weed composition between the vegetation zones is apparent after the effects of crop management have been eliminated, a PCCA was conducted with vegetation zone as the constraining variable and crop rotation regime, previous year's crop, tillage power, sowing date, sowing rate, manuring, and weeding as co-variables. The separation of the vegetation zones remains good when first, the effects of the rotation regime (Fig. 7.45) and previous year's crop (Fig. 7.46) are eliminated individually and secondly, when all the crop management co-variables are eliminated together (Fig. 7.47). The results are all significant at the 0.01 level. These results support the observation that vegetation zone accounts for most of the variation in weed composition.

7.4.1.4 Conclusions

The results of the PCCAs again indicate that vegetation zone is the major variable determining weed composition and that differences due to crop management may be due to chance. From the ordination diagrams, there is a clearer separation of fields according to their previous year's crop rather than their (longer term) crop rotation regime. The results of the Monte Carlo permutation tests of the PCCAs using previous year's crop as the constraining variable are similar to results of the PCCAs using crop rotation regime as the constraining variable.

The same PCCAs were repeated using fields from the hills alone and the significance of the ordination diagrams was again low. The clarity of the ordination diagrams was better and results of the Monte Carlo permutation tests improved in the PCCAs using previous year's crop, rather than crop rotation regime, as the constraining variable. Overall, however, no PCCA using crop management variables to constrain the ordination was significant.

The lack of a significant relationship between crop management and weed composition, could be due to the fact that differences in weed composition of fields in different categories is the result of chance or the fact that there are not a sufficiently large number of fields to establish a significance given the large number of taxa. (Comparison of the CAs and CCAs, however, suggests that the former may be more likely). There are two possible ways of trying to overcome this problem and establish whether crop management is genuinely affecting weed composition. The first is to reduce the number of taxa involved in the analyses. The second is to try to determine whether any of the known ecological or physiological characteristics of individual taxa can explain their behaviour in the analyses.

7.4.2 Reduced Taxa Analyses

7.4.2.1 All Fields Together

It is probable that the large number of taxa - in comparison to the low number of fields - mean that it is difficult to establish a significance for the PCCAs using crop rotation regime and previous year's crop as the constraining variables. In order to test this, the number of taxa was reduced using the following procedure. Using the PCCAs with either crop rotation regime or previous year's crop as the constraining variable and vegetation zone as the co-variable, the taxa that appeared to be the most responsive to crop rotation regime and previous year's crop - the taxa positioned furthest from the origin and in the same direction as each crop management category - were identified. In future, these taxa will be referred to as 'indicator taxa' (cf. Jones *et al.* in press). Following this procedure, the PCCAs were rerun using only the 'indicator taxa' to see if a significant result would result.

In a second set of analyses, three randomly selected fields from each category were removed and the PCCAs repeated using either crop rotation regime or previous year's crop as the constraining variable and vegetation zone as the co-variable. Following previous procedure, the 'indicator taxa' for each category were again identified. The PCCAs were then rerun but with the fields which had previously been removed from the analyses included and made 'passive'. If the 'passive' fields are located on the plots in the same direction as fields from the 'correct' category, then this suggests that the 'indicator taxa' indicate differences in crop management practice and are not included only by chance.

As previous year's crop seemed to be the crop management variable which had the more detectable effect on weed composition, the PCCAs using this variable as the constraining variable are described first.

From the PCCA using previous year's crop as the constraining variable and vegetation zone as the co-variable, one smaller and one larger set of 'indicator taxa' were identified. One set included 50 taxa whilst the second included 28 taxa. For both sets, there are fewer taxa than fields (54 fields). In the PCCAs using the two sets of 'indicator taxa', there is a good separation between the categories (Fig. 7.48a and Fig. 7.48b), although there is perhaps slightly more overlap between the categories when only 28 taxa are used. The results are significant (for 50 taxa $p = 0.05$; for 28 taxa $p = 0.02$). When three fields from each category were removed from PCCAs and then included as 'passives' with 44 and 24 taxa, the fields group reasonably well with the 'correct' category (Fig. 7.49a and Fig. 7.49b respectively), although the allocation is less good when fewer taxa are used (Fig. 7.49b).

From the PCCA using crop rotation regime as the constraining variable and vegetation zone as the co-variable, two sets of 'indicator taxa' were again identified for all the fields. The larger set of 'indicator taxa' included 49 taxa whilst the smaller set included 27 taxa. In the PCCAs using these 'indicator' taxa, there is a reasonable separation between cereal-legume rotation and the rest (Fig. 7.50a and Fig. 7.50b). There is a considerable overlap, however, between cereal-fallow and three year crop rotation regimes (i.e. regimes including a fallow year). The results are significant ($p = 0.04$ and $p = 0.01$ respectively). When three fields from each category were removed from the PCCAs and then included passives, these fields are not situated with their 'correct' category (Fig. 7.51a and Fig. 7.51b).

So, when the number of taxa are reduced, the PCCAs become significant. This suggests that the lack of significance in earlier analyses may be due to the difficulty of obtaining a significant result with such a large number of taxa (compared to the number of fields). In addition, the allocation of the 'passive' fields into their 'correct' categories for the variable previous year's crop adds weight to the suggestion that there may be real, rather than chance, differences in weed composition between fields cultivated under different crop management practices. It may still be, however, that the axes differ by chance. Therefore, in order to test the observed differences in a more rigorous way, the fields were split into two groups and the 'indicator taxa' reidentified. If the same 'indicator taxa' work for both groups, then the differences are very unlikely to be due to chance.

7.4.2.2 Fields Split into Smaller Groups

In order to test further whether the differences in weed composition were due to differences in crop management rather than to chance, the fields were randomly split into two groups (each category was split in two). For each group, the PCCAs using a crop management variable (either rotation regime or previous year's crop) as the constraining variable and vegetation zone as the co-variable were run. The taxa which seemed to be the most responsive to different crop management practices - the 'indicator taxa' - were identified. Next, the PCCAs were rerun; first, using the 'indicator taxa' and then with the second group of fields made 'passive' to see if they would be grouped with the 'correct' categories. Finally, the analyses were rerun using the 'indicator taxa' for the other group of fields. Once again, as previous year's crop seemed to be the crop management variable which had the more detectable effect on weed composition, the PCCAs using this variable as the constraining variable are described first.

In the plots of the PCCAs of each group of fields and their respective 48 'indicator taxa' using previous year's crop as the constraining variable and vegetation zone as the co-variable, there is a good separation between fields which had previously been cultivated with a legume crop, bare fallow and fallow with summer crops (Fig. 7.52a and 7.52b). The results are also significant ($p = 0.05$ and $p = 0.03$ respectively). When the rest of the fields are included in the same PCCAs but made passive, the passive fields only partially group with the respective 'correct' categories (Fig 7.53a and Fig. 7.53b). There is a tendency for most of the passive fields to cluster with fields where the previous year's crop was fallow with summer crops, although in Fig. 7.53a four of the six fields previously cultivated with a legume crop are located with the correct group and one of three fields which had been previously bare fallowed is located towards that category. In Fig. 7.53b, fields previously cultivated with a legume crop are situated towards the legume category but there is some overlap between legume and fallow with summer crops as the preceding crop. When the PCCAs were rerun using the 'indicator taxa' for the other group, there is a good separation between the categories (Fig. 7.54a and Fig. 7.54b) although the plots were not significant (in both cases $p = 0.15$). The good separation but lack of significance reflects the fact that even though the number of taxa has been reduced there are still more taxa than fields. The significance, however, is improved (from $p = 0.30$ to $p = 0.15$).

The PCCAs of half the fields and the 48 'indicator taxa' were repeated using crop rotation regime as the constraining variable. The results were less successful than for the PCCAs using previous year's crop as the constraining variable as there was less clear distinction between the categories. The PCCA using the 'indicator taxa' for each group produced a reasonable separation of the different categories (Fig. 7.55a and 7.55b) and are significant ($p = 0.04$ and $p = 0.05$ respectively). In the PCCAs including the second group as passive fields, however, the passive fields are often positioned 'incorrectly' (Fig. 7.56a and 7.56b). Also, the PCCAs using half the fields with the 'indicator taxa' from the other half produced a less distinct separation between fields cultivated under regimes which included fallow (also noted above for all the fields taken together). The category cereal-legume rotation is still reasonably separate from the rest. The results are not significant ($p = 0.23$ and $p = 0.88$ respectively).

Between the two groups of 'indicator taxa' isolated for previous year's crop, exactly half of the taxa overlap, i.e. 24 out of 48 taxa. Between the two groups of 'indicator taxa' isolated for crop rotation regime, 23 out of 48 taxa overlap. The relatively limited overlap between the groups is perhaps not surprising as using half the fields in the analyses means that, for some categories, the number of fields from which the 'indicator taxa' are being selected is very small. For example, in the bare fallow and a legume crop as the previous year's crop categories, there are only 3 (or 4) and 7 fields included.

7.4.2.3 Conclusions

The results of analyses with reduced numbers of taxa were improved (i.e. the significance was increased) over analyses with more taxa but still not conclusive (in the last analysis for previous year's crop $p = 0.15$). This improvement of the results is supported by the results of the analysis with three passive fields from each category - when the chance element resulting from the selection of taxa based on very few fields is reduced, the analysis is better able - than when the analysis is split in half - to 'classify' the remaining fields correctly. The results also reinforce the observation that the previous year's crop has a more detectable effect on weed composition than longer term crop rotation regimes.

The reduced taxa analyses suggest that some taxa are genuinely responding to different crop management practices while others (most likely those which differ between each half) are included for reasons of chance. Next, therefore, in order to assess the response of taxa, the results of the analyses will be examined using the characteristics of the taxa.

7.5 Species Response to Crop Management Practices

The second approach to assessing whether different crop management practices have a genuine effect on weed composition is to examine the behaviour of taxa in relation to their ecological preferences or physiological characteristics. Unfortunately, there is no summary for the ecological preferences of Near Eastern plant species comparable to that of Ellenberg (1950; 1979) for central Europe. As a result, it is not possible at this stage to assess the preference of the weeds encountered for factors such as nitrogen, moisture, or light. Information relating to the life cycle and germination times of the taxa, however, is available.

7.5.1 Crop Management in Relation to Species Life Cycles and Germination Times

It might be expected that as the number of tillage operations in a crop rotation regime increases, i.e. when fallow (either bare fallow or fallow with summer crops) is practised, persistent perennial weeds will decline. Conversely, when there are fewer tillage operations, as is the case when a legume crop is cultivated in the previous year, perennial weeds may survive and grow alongside the following cereal crop. It might also be predicted that spring tillage (i.e. fallow) may discourage certain weeds; for example, it is likely to discourage autumn germinating weeds. Spring germinating weeds are probably more able to recover from spring tillage depending upon the timing of the operation(s). In order to test these assumptions, the taxa (all those recovered in three fields or more) were classified according to their life cycle and germination time using details given in Zohary and Feinbrun-Dothan (1966-86) and Zohary (1949-50; 1973).

The taxa were classified into five life cycle groups which are: annuals, annuals/biennials, biennial/perennials, annuals/perennials, and perennials (Appendix 7.6a). They were also classified into those which germinate only in the autumn or spring (referred to here as 'monoseasonal') or those which can germinate in either season (biseasonal), i.e. 3 groups (Appendix 7.6b). Most of the taxa recovered are annual weeds which germinate in the winter (a total of 75 taxa).

In the taxa plot of the CCA of all the fields using crop rotation regime as the constraining variable and with the taxa coded according to their life cycle, there is a concentration of perennial weeds with the cereal-legume rotation category (Fig. 7.58a). Perennial weeds, however, are also associated with the other two rotation regimes. When the effect of location in the hills or plains is eliminated from this analysis, either by plotting the taxa resulting from the CCA of the hills fields alone (Fig. 7.59a) or by plotting the taxa from the PCCA with vegetation zone as the co-variable (Fig. 7.60a), the concentration of these perennials with cereal-legume rotation remains reasonably stable. Four perennials are located consistently in the same direction as the cereal-legume centroid and at least three others are positioned towards the edge of this group. The even spread of perennial weeds in the hills and plains vegetation zones (Fig. 7.61a - taxa plot of the CCA using vegetation zone as the constraining variable) suggests that the concentration of these particular perennial weeds with legume-fallow rotation regimes is due to crop management rather than vegetation zone.

When the taxa are coded and plotted according to germination time, weeds which can germinate in either autumn or spring - biseasonal taxa - are associated with regimes including a fallow year. This can clearly be seen in the CCA with crop rotation as the constraining variable (Fig. 7.58b), the same CCA of the hills fields alone (Fig. 7.59b) and the PCCA of all the fields with vegetation zone as the co-variable (Fig. 7.60b). Weeds which germinate only in the spring or in the autumn - monoseasonal taxa are more widely distributed. Biseasonal taxa, however, are more strongly associated with the plains vegetation zone than hills zones (Fig. 7.61b - taxa plot of the CCA using vegetation zone as the constraining variable) which suggests that biseasonal weeds may be related to vegetation zone. Unfortunately, no fields which did not include a fallow year as part of their crop rotation regime were sampled from the plains - making an association between biseasonal weeds and fallow less convincing. When the plains fields are removed, however, there is still an association between biseasonal weeds and regimes including fallow (Fig. 7.59b). It may be, therefore, that biseasonal weeds are associated with the plains because all the crop rotation regimes practised there include fallow rather than that these taxa are 'plains taxa'. Interestingly, all the perennial weeds associated with cereal-legume rotation are monoseasonal whereas approximately half of the perennial weeds associated with fallow regimes are biseasonal. This also perhaps adds weight to the suggestion that biseasonal taxa are associated with fallow (see below).

In the plot of the CCA of all the fields which used previous year's crop as the constraining variable and where the taxa are coded according to their life cycle, comparatively fewer perennial weeds are associated with the cultivation of a legume crop in the preceding year (Fig. 7.62a - CCA of all the fields using previous year's crop as the constraining variable) than were in the same plot when rotation regime was the constraining variable (cf. Fig. 7.58a). Some perennial weeds are still associated with legume cultivation and this remains comparatively stable when the effects of vegetation zone (i.e. location in the hills or plains) are eliminated in the CCA of the hills fields alone (Fig. 7.63a) and the PCCA using vegetation zone as the co-variable (Fig. 7.64a). As the concentration of perennial weeds with cereal-legume rotation is greater than with a legume as the previous crop, it is apparently the presence of a fallow year in the three course rotation regime that disadvantages these perennials relative to annuals. The perennials which are associated with a legume as the previous crop are the same as those associated with cereal-legume rotation. This suggests that these perennials are a result of legume cultivation but that they do not have such an advantage as they do under a continuous cereal-legume rotation regime. A further implication of this is that the long-term cropping pattern is apparently more important for perennial weeds than the short-term.

When the taxa are plotted with the taxa coded according to germination time, weeds which can germinate either in the autumn or spring - biseasonal taxa - are associated with fallow (Fig. 7.62b). As noted above, although biseasonal taxa are associated with the plains, the association between fallow and biseasonal taxa remains comparatively stable when the effects of location in the hills or plains is removed - in the CCA of the hills fields (Fig. 7.63b) and the PCCA with vegetation zone as the co-variable (Fig. 7.64b). Biseasonal weeds - either annual or perennial - are only associated with a preceding fallow year. The strong association of biseasonal weeds with fallow in the previous year suggests that biseasonal weeds have an advantage over monoseasonal weeds in the short-term.

From the above analyses, it is evident that some perennial weeds are associated with cereal-legume rotation. This would seem to support the earlier suggestion that the fewer number of tillage operations associated with legume cultivation allows perennial weeds to persist. On the other hand, biseasonal weeds - both annual and perennial - are associated with fallow perhaps reflecting their opportunistic germinating strategy which allows them to survive repeated tillage. It may also suggest that the perennials associated with fallow are ones that may have germinated recently. Conversely, the perennial weeds which are associated with legume cultivation are all monoseasonal suggesting perhaps that they are established perennials. It is probably significant that the perennial weed which is located in a consistently central position in the ordination diagrams is *Cynodon dactylon* (the world's most pernicious weed) which is a plant that reproduces both by rhizome (when the rhizomes are cut - for instance, by tillage - a new plant grows) and seed. Consequently, it is adapted to succeed under either regime.

In conclusion, the biseasonal and perennial weeds do appear to be responding to crop management practices. There is also the suggestion that in the long-term, legume-cereal cultivation advantages perennial weeds and that in the short-term biseasonal weeds are advantaged by fallowing. The short-term advantage given to biseasonal weeds may also explain the overlap between cereal-fallow and three year crop rotation regimes noted above (see Figs. 7.51a - 7.52b and Figs. 7.55a - 7.57b). The critical factor appears to be the different tillage practices associated with different crops and rotation regimes and especially (but not entirely) the absence of tillage associated with legume cultivation. All this indicates that the patterns observed in the ordination diagrams, highlighting, in particular, the differences between the practice of fallowing and legume cultivation are not entirely due to chance.

7.5.2 Taxa Sensitive to Different Crop Management Practices

In this section, taxa which may be responding to different crop management practices will be suggested. It should be emphasised that these lists are very tentative and almost certainly include some taxa whose appearance is completely due to chance. The taxa are the 'indicator taxa' (see 7.4.2.1) drawn from the PCCAs which use either crop rotation regime or previous year's crop as the constraining variable and vegetation zone as the co-variable. The 'indicator taxa' associated with each category of crop management are given in Table 7.15a (previous year's crop) and Table 7.15b (crop rotation regime) (these are the taxa used for Fig. 7.48a and Fig. 7.50a). The taxa which are common to both groups of fields when they were split in two (see 7.4.2.2) are also marked.

Other than the biseasonal and some of the perennial taxa, it is difficult to explain the presence of certain taxa in this list (or eliminate their inclusion) without further specific knowledge of the ecological preferences of each species. Taxa consistently with legume cultivation (both crop rotation regime and previous year's crop) are: *Ainsworthia trachycarpia, Astoma sesilifolium, Carthamus tenuis, Catapodium rigidum, Crepis aspera, Hypericum triquetrifolium, Ononis antiquorum, Papaver argemone, Rhagadiolus stellatus, Ranunculus arvensis,* and *Trifolium dasyurum.* Of the weeds associated with cereal-legume cultivation *Anchusa strigosa, Astoma sesilifolium, Eryngium creticum, Hypericum triquetrifolium,* and *Ononis antiquorum* are perennial weeds. Taxa consistently associated with fallow (both crop rotation regime and previous year's crop) are: *Bifora testiculata, Bunium elegans, Convolvulus althaeoides, Lagoecia cuminoides, Lallemantia iberica, Lathyrus aphaca, Medicago orbicularis, Ononis natrix, Stachys* *arabica, Turgenia latifolia, Urospermum picroides, Vicia peregrina*, and *Vicia sativa* subsp. *angustifolia*. Of the weeds consistently associated with fallow as the previous crop *Convolvulus arvensis, C. betonicifolius, Euphorbia falcata*, and *Ononis natrix* are biseasonal weeds (three of these can also be perennial weeds). No biseasonal weeds are associated with legume cultivation.

Perennial weeds which do survive fallowing (repeated tillage) may be either 'young' perennials and/or ones which have a strategy that overcomes the effect of repeated tillage. For example, the *Convolvulus* species included in the list are perennials which are associated with fallow but they have very deep subterranean roots which probably enable them to survive repeated tillage (even deep tractor ploughing). *C. arvensis* and *C. betonicifolius* and also can geminate in either the autumn or the spring.

7.5.3 The Hills and Plains Weed Taxa compared with Zohary's Phytosociological Associations

The similarity between the plains and hills weed taxa and two of Zohary's phytosociological segetal associations - the Scolymeto-Prosopidetum farctae and the Ononis leiosperma-Carthamus tenuis respectively of western Palestine (Zohary 1949-50) - were noted in chapter 2. According to Zohary's classification, both associations are within the class Secalinitea orientalia and the order Triticetalia orientalia (see Fig. 2.9). Zohary relates the association Scolymeto-Prosopidetum farcatae (within the alliance Prosopidion farctae segetale) to the heavy soils of the coastal plains and intermountain valleys of western Palestine. The association Ononis leiosperma-Carthamus tenuis (within the alliance Onono-Carthamion tenuis) is associated with the hilly districts (Zohary 1973, 635-639). Taxa found in three fields or more which are character (or preferential/differential) species of these two associations are listed in Table 7.16.

In order to investigate the relationship between these two associations and the hills and plains fields of the study area, a CCA was conducted which took the hills and plains zones as the constraining variable. Taxa which are character (or differential) species of the association Scolymeto-Prosopidetum farctae are located with the plains zone at one end of the resulting ordination diagram and taxa which are character (or preferential) species of the association Ononis leiosperma-Carthamus tenuis are situated with the hills category at the other end (Fig. 7.65). There is, therefore, a very good association between the Scolymeto-Prosopidetum farctae and the plains zone and the Ononis leiosperma-Carthamus tenuis and the hills zone of the study area. Two species (*Silene crassipes* and *Carthamus tenuis*) are located in a central position in the ordination diagram which suggests that the boundary between the two associations may be slightly different in northern Jordan (compared to Zohary's results from western Palestine). It is interesting that three character/preferential species of the association Ononis leiosperma-Carthamus tenuis are associated with the previous cultivation of a legume crop (*O. antiquorum, A. sesilifolium, and Cathamus tenuis* - see Table 7.15 a and b) and one (*Vicia sativa* subsp. *angustifolia*) with the cultivation of fallow with summer crops in the year preceding the cereal year. One species (*E. falcata*) is a differential species of the association Scolymeto-Prosopidetum farctae and also included in Table 7.15a with species associated with fallow with summer crops in the previous year.

7.5.4 *Conclusions*

From the exploration of the individual taxa, it appears that some taxa are responding to different crop management practices. In particular, weeds which can germinate in both the spring and autumn seem to be encouraged when fallow has been practised and persistent perennial weeds seem to be encouraged by legume cultivation. Using PCCAs to eliminate the effect of crop vegetation zone, it has been possible to produce tentative lists of species which appear to be responding to crop management practices (Table 7.15a and b), but some of the species included in the list are almost certainly included due to chance factors rather than crop management. Vegetation zone still remains the major factor affecting weed composition. A comparison of the character/preferential species of Zohary's segetal phytosociological associations from hilly and plains zones in western Palestine and the hills and plains zones of the study area revealed a good correlation. Some of these species, however, apparently characterise different management practices even when the effects of vegetation zone have been eliminated. Therefore, the different phytosociological associations in the hills and plains may partly reflect the different rotation regimes in the different zones.

7.6 Summary

In this chapter, the ecological and physical effects of crop management practices on weed flora have been explored. The results can be summarised as follows:

1. Vegetation zone is the major variable determining weed composition. There is a marked difference between the weed composition of fields located in the hills and plains (which also seems to match differences observed by Zohary for western Palestine) and between the zones of the hills with deciduous and evergreen trees.

2. There is some indication that crop management practices affect weed composition but their influence is equivocal. The low number of fields sampled in certain crop management categories and the high number of taxa compared to the low number of fields has made it difficult to establish significance for the observed patterns (see 3. & 4. below). The high number of taxa mean that it is highly likely that at least some of the taxa which appear to be responding to crop management practices are, in fact, included

only by chance. Reducing the number of taxa included in the analyses confirmed this, but also added some weight to the suggestion that some of the species are indeed responding to crop management practices.

3. The results seem to suggest that short term crop management practices, i.e. how the field was managed in the previous year, have a more determinable effect on weed composition than longer term crop management regimes. It has been difficult to isolate the effect of crop rotation regime partly because, for example, low numbers of fields with non-typical rotation regimes were encountered in the plains zone. This problem is reduced for the variable previous year's crop.

4. Examination of the physiological characteristics of the weeds associated with different crop management practices reveals two interesting trends. First, a preceding fallow year appears to favour presence of weeds which can germinate both in the autumn and the spring - biseasonal weeds - in the following crop. It would appear that because biseasonal weeds can germinate almost at any time, they recover well from the repeated tillage operations associated with fallow. Rotation with legumes appears to allow for the establishment of certain perennial weeds which are advantaged by the reduced number of tillage operations associated with legume cultivation. Perennial weeds which do survive fallowing (repeated tillage) may, therefore, be either 'young' perennials and/or ones which have a strategy that overcomes the effect of repeated tillage. Until there is further information available on the ecological preferences of the weed species of the Near East, it is difficult to interpret the behaviour of the other species.

5. Some interesting trends are visible when all the external variables (environmental and crop management variables) are examined together. For example, there is a linkage between manuring, soil organic content and preceding legume cultivation - suggesting that 'fertility' resulting from crop management practices can be detected in the weed flora. There is also an interesting division between animal and tractor tillage which also suggests that tillage method affects weed composition. The results also reiterate the link between some of the crop management variables which have been discussed in chapter 6. For example, it is evident that farmers in the hills tend to use animal tillage more often and weed and manure their fields more regularly than farmers on the plains.

Chapter 8 Reconstructing and Interpreting Ancient Crop Management Practices

This chapter brings together the two chief components of this thesis: the exploration of agricultural decision-making (the interpretation of human behaviour) and the recognition of crop management practices in the archaeological record via the weeds found in contemporary arable situations (the reconstruction of human behaviour). This thesis has concentrated on crop management practices, and particularly cultivated fallow and crop rotation regimes, as phenomena whose practice is affected by both the natural and social environment.

First, the factors which have been identified as affecting farmers' decisions will be summarised and considered in respect to their effect on crop management practices and their broader application - as factors which allow opportunities for, as well as constraining, long-term change. One of the main conclusions of this study is that human behaviour is affected by a complex interplay of many factors - not, in itself, a new discovery - but, it is important to emphasise that the nature of archaeological evidence (with its many domains of inquiry) does allow archaeologists to interpret complexity and furnish explanations. Ethnographic analogy can inform, refine and challenge those interpretations.

Secondly, the results of the ecological investigation - the study of the effects of crop management on weed composition - are discussed and assessed in this chapter. The intention of this part of the study was to develop a bridge between contemporary and past human behaviour using arable weed behaviour as the intermediary. The way this line of investigation can be developed in future as well as some of the problems encountered will be considered.

8.1 Interpreting Human Behaviour - Constraints and Change

The Mediterranean environment does limit farmers' actions but it does not wholly define their actions - this study illustrates how crop management practices are constrained by both environmental and social/cultural factors. In the course of investigating farmers' decisions, a number of cultural/social factors have been identified which also influence crop management: labour (people), land availability (size of unit and tenure), livestock, technology, market economics, and government policy. Many of these factors have been specifically identified as causing change on a sweeping scale. For example, population pressure has been seen as the impetus for subsistence changes: from hunter-gathering to shifting cultivation, from short fallowing to annual cropping to multicropping (Boserup 1965; 1981). In complex societies, institutional organisations can implement change with apparent disregard for the longer-term carrying capacity of the environment and rely on improvements in technology to overcome problems and allow 'progress' (cf. the contemporary western world). Rather than as causal mechanisms, however, perhaps both environmental and social/cultural factors are best thought of as opportunities and constraints limiting and enabling change (cf. Anderson 1990, 76).

Although in this study the decisions made by farmers were organised according to short, medium and longer term scales (chapter 6), it became evident that this division imposes a structure where the time implications of decisions do, in fact, grade into each other. Apparent ad hoc decisions reflect broader social changes (e.g. the transfer of land from communal to private ownership), and opportunism in the choice of crop cultivated results in the establishment of new crop rotation regimes. New patterns in crop management reflect underlying social trends.

The key factors affecting crop management - which are also factors that influence human behaviour more broadly - are discussed below.

8.1.1 Environment

The environment has often been viewed deterministically, but it has been shown in this study that farming practice is affected by non-environmental factors. It is true, however, that the environment constrains human behaviour (although technology is important here and can help to over-ride certain constraints) and that social changes can be linked to environmental change. Lack of rainfall affects agricultural productivity and over a sustained period this can cause people to, for example, migrate or adopt different subsistence strategies. In the study area during the 1930's, severe drought prompted some nomadic-pastoralists to become settled (although this was also affected by land restrictions - the implementation of national borders - and government encouragement) (Amadouny 1993). It is important that, although environmental deterioration or amelioration may cause change, the response to that change is not predictable.

For farmers working in the Mediterranean, the inter-annual variability in agricultural production caused by variable precipitation means that farmers adopt various coping strategies (Halstead & O'Shea 1989) and, under traditional subsistence regimes, aim to produce a surplus (Halstead 1989). Formerly in northern Jordan, in order to ensure wheat supplies, farmers not only practised bare fallow (generally speaking, the strategy that best ensures the success of the following wheat crop) but also aimed to store enough produce to survive crop failure. This generally means that enough was available to counter short-term shortfalls in production during lean years, but during bountiful years, could mean that wheat - the prestige crop - was fed to livestock (also a way of storing over-production 'on the hoof'). Although cultivated fallow is an agricultural technique adapted to maintaining production under the vagaries of the Mediterranean climate, its adoption is also linked to certain cultural constraints: tillage technology, labour to till, land availability, livestock, settlement patterns and social organisation.

The coping activities that are adopted to deal with the uncertainties of the environment are prone to change, can fall into disuse (e.g. be forgotten by the next generation), or trigger a chain reaction affecting many other aspects of society (Halstead and O'Shea 1989, 125). For example, it has been speculated that the 'normal surplus' produced from farming in the uncertainties of the Mediterranean was commandeered by an emerging elite in Neolithic-Bronze Age Greece (Halstead 1989, 79). This all helps to emphasise that the environment should be considered as a constraint but also as a factor which can initiate change, although the direction of that change depends upon non-environmental factors.

8.1.2 The Importance of People

8.1.2.1 'Population Pressure'

One of the most profound changes in the study area during this century has been the dramatic rise in population. This increase in population in West Asia and North Africa has prompted agronomists to advocate intensive agricultural practice, e.g. continuous cropping and irrigation. Given the increase in population, it is perhaps not surprising that farmers are more likely, under rainfed conditions, to crop annually (cereal-legume rotation and cultivate fallow with summer crops). It does not, however, explain the reluctance of farmers to adopt fertilisers or many other facets of ('advanced') intensive agriculture. Also, significantly, agricultural production in the study area has not significantly improved this century with the increase in population. Farmers have been notoriously resistant to intensification. Demographic pressure is undoubtedly playing a part in changing the rural landscape of northern Jordan (e.g. expanding cultivation into previously uncultivated areas and causing a housing boom) but the effect of off-farm employment which has resulted in local agricultural labour shortages does appear to be having a more profound effect on contemporary crop management practices.

Social organisation and economic climate can also buffer population increases. Without the support of a broader economic structure, the ratio of population to resources renders societies vulnerable to change. The effects of population increases experienced in northern Jordan have undoubtedly been buffered by institutional support, food imports and earnings that are brought in from local employment (e.g. the army) and the oil states.

As with environment, population pressure provides an impetus for change but the direction of that change is not predictable and is dependent upon other factors.

8.1.2.2 Labour Availability

The availability of labour has strong effects on crop management practices in the study area. Availability of family labour means that farmers will weed their crops and be more prepared to cultivate legumes which require 'expensive' hand-harvesting. On the other hand, lack of family labour can mean that legumes are removed from a crop rotation sequence and can prompt farmers to abandon arable cultivation and invest in tree crops. Tree crops are comparatively easy to cultivate, in comparison to arable crops, as their main labour requirements involve tillage (performed to control weed infestation) and harvesting. Tillage can be easily performed by tractors and the olives can be collected by mobilising the whole family during the cooler September/October evenings or by hiring cheap imported labour. This also demonstrates how machinery and hired labour can substitute for family labour.

In the past, one of the major restrictions on agricultural production in the study area was the availability of oxen, ards (scratch-ploughs) and labour to till. Cultivated fallow has been interpreted partly as a response to labour restrictions and scheduling workloads (Halstead 1987). Contemporary tractor powered tillage has eased the restrictions placed on labour in terms of tillage and part of the reason for the persistence of cultivated fallow in the study region is that tractors are substituted for labour (and the fact that land units are smaller - c. 14 dunum of wheat per farmer in the study group).

Farmers are less able to draw on kin-based networks of support than in the past and this has served to reduce the pool of available labour for agricultural activities. Social organisation, therefore, also affects crop management and was, for example, very important in the operation of the former system of communal farming (mushā'a) that existed in northern Jordan. People who are brought in to help with, say, the legume harvest today require cash payment rather than a present in kind (or the expectation of help in return should the need arise) even if they are relatives. This can lead to the elimination of the legume crop from a crop rotation sequence. The reduced ability to draw upon kin-based networks of support has also contributed to a general decline in 'good' management practices such as weeding and manuring (also see the discussion on the advantages of communal farming below). It is significant that farmers who own/cultivate land with relatives are more likely to weed.

It is one of the contradictions of contemporary life in northern Jordan that, despite the massive increases in population seen in the area, there is a shortage of local agricultural labour. This has been caused by off-farm employment, schooling for children, the loosening of kin-based networks of support, and an ageing local agricultural workforce. Labour availability is also not only affected by the number of people in a household but also by the age and sex of the members. A household dominated by very young members cannot contribute much labour and has comparatively high demands. Today, even in households with mature members, labour is not always available as members may be working full-time or even unwilling to participate in low prestige agricultural work. The farming household with members working off the farm has the benefit, however, of being 'buffered' by external incomes - these incomes do not rely upon the uncertainties of the Mediterranean climate (although they rely on the uncertainties of the modern economic system). Farm labouring (and subsistence activities generally) is also a comparatively low status occupation and the younger generation prefer, if they can, to find other employment.

8.1.3 Technology

Technology (or innovations such as new crops), like population pressure and environmental change, has been viewed as a cause of change. Recently, however, it is more generally acknowledged as an instrument rather than a cause of change and a dependent rather than an independent variable. Population pressure and the desire for economic progress, for example, are prompting agronomists to search for ways to increase agricultural production. They are developing the technology for intensification, but farmers are frequently choosing not to adopt it.

The adoption of technology depends upon that knowledge being there but also upon available capital. Farmers are unwilling to invest in fertilisers or hybrid wheats simply because they do not have the cash. The explanation, however, is more complex and ties back to the uncertainties of the Mediterranean environment - farmers are unwilling to invest when they are aware that all can be lost in a bad season. They would rather secure a reasonable yield than take the risks associated with a better one. One of the reasons given by Mandate officials for the necessity to break-up communal land tenure was that it would allow farmers to mortgage their land and therefore, provide them with cash to invest in it with the prospect of improved yields in the future. Farmers did mortgage their land, but most often in response to a bad season (or seasons) and consequently, some became tenant farmers on their own land (Fischbach 1990). Private ownership, however, has enabled farmers to invest in trees but there are other factors influencing this decision - most notably their ease of cultivation (low labour requirements) and good monetary returns.

Adoption of technology is also dependent upon the prevailing institutional or economic structure. For example, under the communal system of land tenure, although local farmers possessed the knowledge to terrace land and irrigate (this was done in local orchards and people collected water for human and animal consumption) they were prevented by the tenural system from implementing these changes. It is important to bear in mind, however, that the former agricultural system, with cultivated fallow as a core component, had other advantages for farmers such as providing animal grazing and making good use of scarce labour and plough animals.

'New' crops are often adopted due to other influences. For example, although dhura (sorghum) was known in Syria from the 7th century AD, its cultivation dramatically increased in the Levant during the seventeenth century due to its association with the 'çiftliks' (managed estates) and the market-orientated transformation of agrarian structures that followed their rise (Tabak 1991, 143-146). Other summer crops (many from the New World) were also adopted at that time and became a regular part of crop rotation regimes in the western, particularly coastal, Levant. In other words, summer crops were - and are - important cash crops. The proliferation of summer crops in northern Jordan in recent years also parallels the privatisation and commercialisation of agriculture.

In general, therefore, reasons are required to prompt the adoption of an innovation. People are constrained by technology if a technique is not known, the impetus to adopt does not exist, or an institutional structure prevents adoption. Contemporary farmers in northern Jordan are suspicious of new techniques (including improved crop varieties) because they do not know their risks. In general, people would rather maintain what they know - this 'conservatism', however, is also 'stabilising'.

8.1.4 Land

8.1.4.1 Land Tenure

One of the most interesting aspects of former arable land management in northern Jordan was the existence of communal land tenure, or mushā'a - a system where arable land was redistributed between members of the village or group at regular intervals. A number of explanations has been offered to explain this phenomenon which was also found more generally in the Levant (see 2.6). In sum, however, mushā'a seems to be a strategy which coped with the constraints of the environment, promoted internal social solidarity (for example, it curbed the differential accumulation of wealth), and enabled communities to bear the dangers of bedouin raids or Ottoman tax burdens.

In terms of crop management, communal tenure meant that many operations and decisions were carried out on a group basis. For example, what to sow (and therefore, the crop rotation regime) was decided together and the cereal harvest was undertaken together. Cultivated fallow was an integral component of mushā'a. The way communal farming was practised in the Levant provides an important example (possible interpretative model) of collective farming and is another example of how private ownership should not be assumed for the past. Furthermore, it illustrates how large extensively farmed units of land can be managed without the presence of, for example, an estate manager, overlord, or ruling elite. Cultivated fallow (and 'extensive' agriculture), therefore, is not only associated with large 'estates' (cf. Halstead 1992a). As it has been argued that mushā'a is a response to oppressive taxes (Firestone 1981;1990), however, it could be argued that extensification was a means by which high levels of surplus production were attained (Halstead 1992, 111) to fulfil fiscal demands.

Examination of recent rural history and rural archaeology is providing increasing examples of how land tenure affects settlement patterns and cropping regimes. For example, Whitelaw (1991) has related changes in the spatial organisation of different elements of the agricultural and settlement system in northern Keos (in the Cycladic islands in Greece) over the past two centuries with important land reforms. Specifically, he relates a shift from nucleated to dispersed settlement to the dissolution of monastic estates, the abolition of the practice of joint tenancy of agricultural land, and increased sale or rental of farmland. For the Ottoman period, Davis (1991) suggests that the system of land tenure on Keos and Seriphos (also in the Cycladic islands) explains the absence of isolated farmsteads (i.e. dispersed settlement) - farmers did not hold the consolidated plots necessary to make residence viable. Land tenure, in this case, gives a certain amount of archaeological 'invisibility'. Davis also argues that this system - where land ownership was not only fragmented but also entailed the dual ownership of agricultural land with one 'owner' who retained grazing rights - prevented the use of intensive agricultural practices (Davis 1991, 195-6). In addition, the income that could be raised through the sale of cash crops (on Keos this was *velanidi*, acorn cups), meant that intensive grain production was not required to fulfil tax obligations.

Under the system of mushā'a, the landscape was characterised by nucleated villages and a lack of permanent field boundaries due to periodic redistribution of arable land as well as separate tree and arable cultivation. The association between open-field farming and the rotation of communal agricultural land and nucleated settlements has also been made for Europe (Davis 1991, 202). Communal tenure and collective land organisation, however, may not always have resulted in nucleated settlements but other contributing factors are important such as climate, land quality, inheritance rules, and broader economic and institutional structures. Ethnographic analogies, of course, always require care in their application - other factors can cause or contribute to a similar phenomenon. In north-western Europe, for example, collective organisation and kin-based networks have been offered as explanations for Bronze Age (Fleming 1985, 135) and Roman (Williamson 1989, 82) dispersed settlement patterns. Both these interpretations are primarily based on a system of communal land-holding formerly practised in Wales. Nucleation is seen as representing, in later periods, incorporation into a broader economy and the evolution of estate farming (Williamson 1989, 82).

In northern Jordan, the break-up of communal ownership (1930's to 1950's) and transfer to individual private ownership has allowed for greater flexibility in land management. Continuous cropping regimes can be adopted more readily and trees can be planted on former arable land. In this respect, private ownership has facilitated flexibility and in some cases, promoted intensification. It has also contributed to the fragmentation and dispersal of settlements. In addition, new field boundaries and terraces are being established. There are disadvantages, however, as individual ownership can mean there is insufficient labour or money to perform certain tasks - it has been argued that collective farming can actually increase, rather than decrease, agricultural productivity (see below).

In this study, renting land tends to promote continuous cultivation, although usually without the 'good management practices' associated with intensive cultivation e.g. manuring and weeding. Farmers who rent tend to minimise inputs whilst maximising output. Farmers who own land tend to invest more in it - this can mean more regular fallowing, weeding and manuring. Mushā'a, like renting, has been linked with lack of investment and overuse by farmers (the main criticisms of the system voiced by British officials). The same criticism has been noted by other commentators for communal farming in other parts of the world; for example, the Medieval English open field system (e.g. Dahlman 1980 in Fleming 1985, 139). There are advantages to communal farming, however, and it has been suggested that collective property rights and decision-making can be quite consistent with private wealth maximisation and also mean increased productivity (Fleming 1985, 138-143). Principally, there are economies of scale which are highly advantageous; for example, there are lower transaction costs incurred policing and maintaining boundaries, and a communal shepherd is a low cost method of herding (Dahlman 1980 in Fleming 1985, 139). There is also the factor that working communally relieves much of the work burden. Harvesting together, for example, helps to maintain morale for a hard job which has to be done quickly (see, for example, Abujaber's 1989 descriptions of the former harvest season at al-Yaduda farm). Building enterprises can also be more easily undertaken by groups. In the study group, farmers who held their land with other family members were more likely to practice good crop management (e.g. weeding) not only because the labour was available but because there is a collective responsibility to each other. Therefore, communal farming has many advantages. Finally, the way mushā'a was formerly organised also gave individuals a certain amount of flexibility; for example, both Firestone (1981; 1990) and Tabak (1991, 150) comment that the redistributive practice allowed a considerable degree of mobility for labour. This kept the agricultural land productive but also meant it continued to be maintained by members of the same kin-group (i.e. it maintained the prevailing kin-based social structure).

Land tenure, therefore, appears to be a very important factor affecting agricultural decision-making and settlement patterns. Furthermore, politically motivated agendas entailing land redistribution are not only a recent phenomenon - Davis cites examples from the 5th century BC and the Byzantine period (Davis 1991, 202). Neither are land reforms always centrally directed (e.g. Whitelaw 1991).

8.1.4.2 Land Unit Size

Land availability affects the adoption of intensive or extensive agricultural systems. For example, cereal-fallow regimes where tillage is performed by plough teams generally require more land - production is increased/maintained by cultivating more land rather than by increasing production per unit area (i.e. intensification). Incidentally, land availability is not only limited by population density (given a cultivable soil and sufficient precipitation) but can be limited by socially imposed boundaries. For example, the extensive agricultural system used in the Mediterranean takes up large tracts of land leaving too little for other people.

Lack of land can result in the adoption of more intensive agricultural management practices - unless supplies can be gained from elsewhere - but an 'excess' of land does not always mean that practices associated with extensive agriculture will be adopted, i.e. intensive systems can be used when land is plentiful. There is not a straightforward inverse correlation between farm size and land productivity and other factors have to be taken into consideration (cf. Barbier 1984).

The consolidation of land units is also important. Fragmented plots some distance away from each other and some distance from a settlement do not promote investment or allow for intensification (Davis 1991, 193-195), although holding plots in different areas on different qualities of land spreads the risk of crop failure (Forbes 1976; Halstead and Jones 1989, 51). One advantage of mushā'a was that although farmers held fragmented plots, each crop was grown together in a continuous block which, for example, prevented losses from animal damage and reduced weed growth (the lack of permanent field boundaries meant that weeds were not harboured along field boundaries).

8.1.5 Livestock

Of all the factors in this particular study, ownership of livestock appears to have the most detectable effect on crop management. Livestock holding is important for both cereal-fallow and cereal-legume rotation regimes.

In this study, the adoption of a cereal-legume regime was found to be strongly associated with the ownership of animals. The adoption is not entirely unrelated to other factors - for example, it is linked to the fact that land registration has limited grazing territory and labour availability - but it does serve to emphasise that providing fodder and grazing is key to understanding many agricultural systems. As noted above, the provision of fodder and grazing is also an important component of cereal-fallow regimes. Perhaps in the case of cereal-legume regimes, the key factors are restricted land availability combined with immobility, and, particularly for farmers with larger herds, commercialisation. In cereal-fallow regimes it is probable that greater land availability (both communal arable land and communal grazing), the prevailing system of land tenure, and the maintenance of oxen as traction animal are important. Once again, other facets of the whole society have to be taken into consideration.

With such a clear integration between crop rotation regimes and animal-holding, it is intriguing to speculate whether the domestication of animals (and milk production) was accompanied by the adoption of regular crop rotation regimes. Animals also provide the manure that is usually a necessary part of intensive agricultural practice.

8.1.6 Markets - Economic Forces

The market offers farmers a powerful incentive to increase productivity and specialise. For most small-scale farmers, production is intended for the household and, particularly in respect of arable production, farmers generally aim to secure a crop rather than maximise production for the market. In addition, as the price for many arable crops is fixed at a comparatively low level, there is even less incentive to increase production. For food staples, there is also the problem that even where prices are not fixed increased production generally means lower market prices - unless demand is increased (by export, for example). This can also act as a disincentive to intensify.

It is in the cultivation of summer crops and olives that the effects of the market are perhaps most evident. Tobacco and watermelon are both valuable cash crops and olive oil commands a high price. Although many summer crops are, in fact, intended for home consumption - their value is largely in the saving they bring (these products do not have to be bought) - the market price certainly affects the choice of crop.

Although cash cropping may seem a comparatively recent economic phenomenon, when it is slightly rephrased as producing a 'valuable' crop for sale or exchange; the practice immediately appears to have a greater time depth and geographical application. Davis has argued that cash crops alleviated heavy Ottoman tax demands which were paid in money and consequently, the intensification of grain production was less imperative (Davis 1991 and see 8.1.4.1). Producing more grain, therefore, is not the only way to pay taxes or increase revenue.

In contemporary Jordan, off-farm employment has a dramatic effect on agricultural practice - causing shortfalls in agricultural labour. The income received from outside employment is usually essential for the survival (and prosperity) of the household and often means agricultural work is secondary to paid work. Also, when farmers are assured an income from elsewhere, the pressure to intensify production is undermined.

8.1.7 Social and Institutional Organisation

When the Ottomans re-established their authority over northern Jordan in the late nineteenth century, one of the main effects was to promote settlement in the study area. The Ottoman land reforms also helped to change the pattern of land use in favour of the agriculturalists (Amadouny 1993, 76). There was new settlement by outsiders but it is also evident that local villagers also moved from a number of key settlements to (re-) establish new settlements. Mushā'a operated in such a way that large tracts of dispersed agricultural land were cultivated which were often some distance away from the main settlement. For example, older farmers from villages around Tibna explained that before their particular village was formed their predecessors used to be based in Tibna and move out to different (periodically redistributed) agricultural lands when necessary, i.e. to plant and harvest. These blocks of agricultural land have subsequently been allocated to different kin-groups (by both the Ottomans and the British) and become permanent villages and village lands. This account ties in with the account given by Antoun (1972) of the tribes moving out from Tibna. On a smaller scale, another farmer described how the villages of Kufr 'An and Qam were founded at the turn of the century by villagers who came from Haufa (in this case, it was not absolutely clear whether the lands were previously farmed by these villagers).

Other ways in which social and institutional organisation have affected agriculture in the study area have been discussed previously. For example, during the Mandate, land settlement brought a profound change in the relationship between farmers and their land. Following land settlement, farmers held a consolidated plot, or plots, with fixed boundaries and the freedom to cultivate what they desired as, for example, an individual or smaller family group. Agricultural decision-making was transferred, therefore, from broader alliances (tribally or village based) to smaller and more independent units. The important implications of communal and private ownership have been discussed in 8.1.4.1.

8.1.8 Implications for Archaeology

There are a number of archaeological implications which can be summarised as follows:

1. Crop management practices are affected by social constraints and, for example, the use of cultivated fallow is linked to livestock-holding, land tenure, and labour availability.

2. The complex interplay of factors affecting human behaviour can be interpreted - the nature of archaeological evidence, with many realms of inquiry, potentially allows insight on many domains e.g. crop management practices (weed assemblages), livestock holding (faunal remains), land use, land tenure and social organisation (settlement patterns and 'field systems'), social organisation (e.g. the nature of storage features and their placement), and land use (soil studies and pollen analysis).

3. Land tenure (both as a component of social organisation and as a phenomenon affecting the organisation of society) has perhaps been a previously understudied factor and would appear to require more attention from ethnoarchaeologists and archaeologists. More research is required on the operation of communal farming systems and the link between land tenure and social organisation.

4. Tree crops and summer crops also indicate intensification of land use. They have the potential to provide a better 'income' than grain crops (hence investment in, for example, terracing and irrigation). These types of crops are less often preserved in the archaeological record (although there is, of course, archaeological evidence for terracing and irrigation).

5. For an innovation (including technological innovations) to be adopted, an impetus is generally required - farmers will not adopt, for example, new crops without perceivable internal advantages or without external pressures (extending from both natural and social domains, e.g. drought or fiscal demands). This explains the much quoted 'conservatism' or 'stability' of rural society. Once adopted, however, those innovations may in turn affect the organisation of that society and, for example, crop rotation regimes. The adoption of an innovation would often appear to reflect change in some other domain.

8.2 The Identification of Crop Management

8.2.1 Crop Management Practices and Weed Composition in the Study Area

In order to enable crop management practices to be identified from archaeological weed assemblages, the contemporary weed flora of fields managed under different crop rotation regimes were examined. Correspondence analysis proved very successful at enabling patterns in the weed data to be detected (using simple CA) and attributed to certain key external variables (using CCA where external variables are used to constrain the ordination). It also allowed associations to be seen between the external variables.

In this study, vegetation zone was the major variable determining weed composition. There was a marked difference between the weed composition of fields located in the hills and plains (which also seems to match differences observed by Zohary (1949-50) for 'Western Palestine') and between the zones of the hills with deciduous and evergreen trees. There was some suggestion, however, that the different crop rotation regimes used, in mountainous and plains areas in both contemporary northern Jordan and western Palestine, contribute to the observed differences in weed composition.

There was an indication that crop management practices affect weed composition both on the short (previous year's crop) and longer term (crop rotation regime). The low number of fields sampled in certain crop management categories, and in particular the high number of taxa compared to the low number of fields, made it difficult to establish the significance of the observed patterns. The high number of taxa makes it highly likely that at least some of the taxa which appeared to be responding to crop management practices were, in fact, included only by chance. This requires further investigation.

Examination of the physiological characteristics of the weeds associated with different crop management practices revealed two interesting trends. First, the inclusion of a fallow year in a crop rotation sequence appears to favour presence of weeds which can germinate either in the autumn or the spring - these biseasonal weeds are well adapted to survive the numerous tillage operations associated with fallow. Continuous cereal-legume cultivation, on the other hand, appears to encourage the establishment of certain perennial weeds - in this case, it would seem that the reduced number of tillage operations associated with legume cultivation is important. Perennial weeds which do survive fallowing (repeated tillage) may, therefore, be either 'young' perennials and/or ones which have a strategy that overcomes the effect of repeated tillage (for example many *Convolvulus* spp. have very deep roots).

Farmers in the study area noted four local weeds (or group of weeds) which are encouraged by legume cultivation. They are *Galium tricornutum*, *Hypericum triquetrifolium*, *Cistanche* spp., and a forth species which was not identified. *H. triquetrifolium* was associated with legume cultivation in the study but *G. tricornutum* appeared as an ubiquitous weed. *Cistanche* spp. were not found in the study of field weeds. Members of this genus, however, flower early (March and April) and may have died back before the field survey started in May. Farmers also observed that different weeds are associated with summer crops; for example, *Euphorbia aleppica* and *Convolvulus* spp.. Farmers on the plains, also noted that *Ononis antiquorum* and *Bifora testiculata* decrease with tractor ploughing.

8.2.2 The Nature of Weeds - Responses to Different Crop Management Practices

Other research into weed ecology emphasises that it is not only climate and soils which influence weed composition but also crop management. This research stresses the different nature of weeds: their life cycle, reproductive strategy, germination requirements, dormancy period, and regenerative ability. For example, the different weeds associated with autumn and spring sowing (in central and northern Europe) have been comparatively well documented (Ellenberg 1950). Also, and as in this study, one of the main factors affecting the survival of weeds in the field appears to be tillage - the timing and frequency of the operations and the response of different weeds to tillage. For example, in a study of the occurrence of perennial weeds in different crops (different annual crops and leys) in Sweden, the ability of a perennial to develop in a crop depended upon its capacity for regeneration after tillage - 'wandering plants' with strong underground rhizomes or with thickened plagiotropic roots had the highest capacity for regeneration (Håkansson 1982, 125-6). In the Swedish study, perennial weeds were also a feature of longer term cropping with low levels of tillage - they did not feature prominently after only one year.

Annual species are more responsive to immediate change and are dominant in arable crops. This is true even where, for example, weed killers and reduced tillage are used - in these cases it appears that annual grasses increase while dicotyledonous annuals decline (Froud-Williams *et al.* 1981). The long dormancy of many weed species means that although some species may be seen to 'disappear', they are in fact stored in persistent buried seed banks and can reappear should conditions (environmental or crop management practices) become optimum (Holzner *et al.* 1982).

In general, it is not possible to use weeds as indicators of single nutrients in the soil - that is, looking for the presence of one mineral which may be due to, say, legume cultivation. This is largely due to competition between weeds (Holzner 1982, 188 and see the discussion on phytosociology in section 1.5.2). General soil fertility may, however, be possible to trace alongside differences caused by 'mechanical' factors (e.g. different tillage practices and grain cleaning). The investigation of weeds' germination requirements and regenerative strategy (i.e. how they compete), for example, appears to have great potential for future investigation.

8.2.3 Future 'Fields' of Research

Although some interesting trends were isolated (for example, the tendency for some perennial weeds to be associated with cereal-legume cultivation) more research is required to establish the significance of, and understand, the observed differences. This could be approached in four ways:

1. More field sampling for cereal-legume and three year rotation regimes in the hills and two year regimes on the plains. A larger number of fields would have to be sampled to overcome chance differences in species compositions. A total of at least one hundred fields would be required (to exceed the number of taxa found in 3 fields or more) - preferably with equal numbers of fields in the hills and plains and equal numbers in each crop management category.

2. A better understanding of the physiological or ecological characteristics of each taxon would also help to assess whether some of the taxa linked with say, cereal-legume cultivation, were present due to chance or not. For example, G. Jones and M. Charles are investigating the physiological characteristics of taxa found under irrigated conditions in Spain. It would be interesting to find out more about the response of different taxa to tillage - which are killed and which can re-establish themselves quickly (i.e. different species' regenerative strategies). In would also be advantageous to know the response of weeds to good soil conditions (for example, caused by manuring or cereal-legume rotation).

3. Controlled long-term experiments could be established to investigate weed floras and crop management regimes. This is the most expensive of the four suggestions but would help, if conducted over a long period, to factor out one of the variables that has not been considered in this analysis (which was only conducted over two years) - inter-annual variation in precipitation. This proposal may be less difficult to establish than imagined as co-operation with one or more of the agricultural stations who are already conducting long term investigations into different crop rotation regimes (e.g. the ICARDA station at Tel Hadya) could prove highly productive.

4. Finally, as the crop cultivated in the previous year affects weed composition in the following year, it may be profitable to study weeds associated with different crops.

There is some urgency in conducting more investigations as traditional crop management practices are disappearing in the study area and in the Levant generally. As the older generation of farmers die, not only is their knowledge being lost but also the potential to examine 'traditional weed floras'. Tractor tillage and modern seed cleaning methods as well as weed killers all affect field weed composition.

8.3 Archaeological Reconstruction and Interpretation - Conclusions

Crop management practices are not simply a product of the environment - cultural and social factors are also critical. This study has illustrated how, for example, animal husbandry, social organisation, and labour availability affect crop management and in turn, how those practices affect society. The study of contemporary behaviour enables potential mechanisms of change to be detected and the results to be used as a guide to the questions we should be asking about the past. The factors that have been discussed neatly integrate with many lines of archaeological evidence, for example, technology, settlement patterns, faunal remains, and, of course, archaeobotanical data. Thus using ethnographic analogy to interpret different forms of archaeological evidence, it should be possible to understand how past societies may have operated and what caused them to change.

The second aspect of this thesis was to establish criteria for the recognition of ancient crop management practices. Examination of fields cultivated under different rotation regimes suggests that 'intensive' cereal-legume rotation gives rise to a subtly different weed flora than regimes which include cultivated fallow. This work, however, requires further substantiation as well as a better understanding of the ecological requirements and physiology of weeds. So far, however, tillage patterns have emerged as a critical factor affecting weed composition. At present, researching the physiology rather than the ecology of weeds (e.g. response to specific nutrients) appears to have greater potential.

The final stage in these investigations is to compare the results of the contemporary weed studies with weeds found accompanying ancient cereals to determine which crop management practices can be identified. The results can then be interpreted in the light of the factors affecting farmers practising different crop rotation regimes today and alongside complementary archaeological evidence.

Bibliography

Abujaber, R. S. (1989). *Pioneers Over Jordan. The Frontier of Settlement in Transjordan, 1850-1914.* I. B. Tauris & Co. Ltd., London.

Abu-Lughod, L. (1989). Zones of Theory in the Anthropology of the Arab World. *Annual Review of Anthropology,* 18, 267-306.

Amadouny, V. M. (1993). *The British Role in the Development of an Infrastructure in TransJordan During the Mandate Period, 1921-1946.* PhD Thesis, University of Southampton.

Amor, R. L. (1991). Effect of Weeds on Water Use of Rainfed Crops. In H. C. Harris, P. J. M. Cooper, M. Pala (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas.* ICARDA, Aleppo, Syria. 199-203.

Anderson, J. L. (1991). *Explaining Long-Term Economic Change.* Basingstoke, Macmillan Education Ltd..

Antoun, R. T. (1972). *Arab Village. A Social Structural Study of a Trans-Jordanian Peasant Community.* Indiana University Press, Bloomington.

Arabiat, S., Nygaard, D., Somel, K. (1983). *Factors Affecting Wheat Production in Jordan.* ICARDA, Aleppo, Syria.

Arnon, I. (1972a). *Crop Production in Dry Regions. Vol. 1: Background and Principles.* Leonard Hill, London.

Arnon, I. (1972b). *Crop Production in Dry Regions. Vol. 2: Systematic Treatment of the Principal Crops.* Leonard Hill, London.

Avitsur, S. (1975). The Way to Bread. The Example of the Land of Israel. *Tools and Tillage,* 2 (4), 228-241.

Aydin, Z. (1990). Agricultural Labour and Technological Change in Jordan. In D. Tully (ed.) *Labour and Rainfed Agriculture in West Asia and North Africa.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 185-208.

Bahl, P. N. (1990). The Role of Food Legumes in the Diets of the Populations of Mediterrnaena Areas and Associated Nutritional Factors. In A. E. Osman, M. H. Ibrahim, M. A. Jones (eds.) *The Role of Legumes in the Farming Systems of the Mediterranean Areas.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 143-149.

Bailey, H. P. (1979). Semi-Arid Climates: Their Definition and Distribution. In A. E. Hall, G. H. Cannell and H. W. Lawton (eds.) *Agriculture in Semi-Arid Environments.* Springer Verlag, Berlin. 73-97.

Barbier, P. (1984). Inverse Relationship between Farm Size and Land Productivity. A Product of Science or Imagination. *Economic and Political Weekly,* 19 (52 & 53), 189-198.

Basson, P. (1981). Women and Traditional Food Technologies: Changes in Rural Jordan. *Ecology of Food and Nutrition,* 11, 17-23.

Beaumont, P. (1985). Man-induced Erosion in Northern Jordan. In A. Hadidi (ed.) *Studies in the History and Archaeology of Jordan II.* Department of Antiquites, Amman, Hashemite Kingdom of Jordan. 291-296.

Behre, K.-E. and S. Jacomet (1991). The Ecological Interpretation of Archaeobotanical Data. In W. van Zeist, K. Wasylikowa and K.-E. Behre (eds.) *Progress in Old World Palaeoethnobotany.* A. Balkema, Rotterdam. 81-108.

Bender, F. (1974). *Geology of Jordan.* Supplementary edition in English with minor revisions. Translated from the German in co-operation with the Natural Resource Authority, Amman, Jordan, by M. K. Khdeir in association with D. Parker and U. Wilkening. Gebrüder Borntraeger, Berlin-Stuttgart.

Bender, F. (1968). Geological Map of Jordan 1:250 000 - 5 sheets. Geological Survey of the Federal Republic of Germany, Hannover.

Bergheim, S. (1894). Land Tenure in Palestine. *Palestine Exploration Fund, Quarterly Statement,* 20, 191-199.

Binford, L. R. (1977). General Introduction. In L. R. Binford (ed.) *For Theory Building in Archaeology.* Academic Press, New York. 1-10.

Binford, L. R. (1981). *Bones: Ancient Men and Modern Myths.* Academic Press, New York.

Boardman, G. and Jones, G. (1990). Experiments on the Effects of Charring on Cereal Plant Components. *Journal of Archaeological Science,* 17, 1-11.

Bolton, F. E. (1991). Tillage and Stubble Managment. In H. M. Harris, P. J. M. Cooper, M. Pala (eds.) *Soil and Crop Managment in Improved Water Use Efficiency in Rainfed Areas.* Aleppo, Syria, ICARDA, 39-47.

Boserup, E. (1965). *The Conditions of Agricultural Growth: the Economics of Agrarian Change under Population Pressure.* Allen & Unwin, London.

Boserup, E. (1981). *Population and Technological Change: a Study in Long-Term Trends.* Blackwells, Oxford.

Braak, C. J. F. ter (1985). Correspondence Analysis of Incidence and Abundance Data: Properties in Terms of a Unimodal Response Model. *Biometrics,* 41, 859-873.

Braak, C. J. F. ter (1986). Canonical Correspondence Analysis: a New Eigenvector Technique for Multivariate Direct Gradient Analysis. *Ecology,* 67 (5), 1167-1179.

Braak, C. J. F. ter (1987-92). CANOCO - a FORTRAN Program for Canonical Community Ordination. Ithaca, New York, Microcomputer Power.

Braak, C. J. F. ter (1988). A FORTRAN Program for Canonical Community Ordination by (Partial) (Detrended) (Canonical) Correspondence Analysis and Redundancy Analysis (Version 2.1). TNO Institute of Applied Computer Science, Wagenigen.

Braun-Blanquet, J. (1964). *Pflanzensoziologie.* Springer, Wein (third edition).

Briggs, D. (1977). *Soils.* London, Butterworths.

Brown, S. C., Keatinge, J. D. H., Gregory, P. J., and Cooper, P. J. M. (1987). Effects of Fertiliser, Variety and Location on Barley Production in Northern Syria. 1. Root and Shoot Growth. *Field Crops Research,* 16, 53-66.

Buddenhagen, I. W. (1990). Legumes in Farming Systems in Mediterranean Climates. In A. E. Osman, M. H. Ibrahim, M. A. Jones (eds.) *The Role of Legumes in the Farming Systems of the Mediterranean Areas.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 3-29.

Bunting, A. H. (1960). Some Reflections on the Ecology of Weeds. In J. L. Harper (ed.) *The Biology of Weeds.* Blackwell, Oxford. 11-26.

Burckhardt, J. L. (1822). *Travels in Syria and the Holy Land.* John Murray, London.

Burdon, D. J. (1959). *Handbook of the Geology of Jordan.* Amman, Government of the Hashemite Kingdom of Jordan.

Burwell, R. E., Allmaras, R. R. and Sloneker, L. L. (1966). Structural Alteration of Soil Surfaces by Tillage and Rainfall. *Journal of Soil Conservation*, 21, 61-63.

Callaway, H. (1992). Ethnography and Experience: Gender Implications in Fieldwork and Texts. In J. Okely and H. Callaway (eds.) *Anthropology and Autobiography.* Routledge, London. 29-49.

Capper, B. S. (1990). The Role of Food Legume Straw and Stubble in Feeding Livestock. In A. E. Osman, M. H. Ibrahim, M. A. Jones (eds.) *The Role of Legumes in the Farming Systems of the Mediterranean Areas.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 151-162.

Castri, F. di (1981). Mediterranean-Type Shrublands of the World. In F. di Castri, D. W. Goodall and R. L. Specht (eds.) *Mediterranean-Type Shrublands.* Ecosystems of the World 11. Elsevier Scientific Publishing Co., Amsterdam. 1-52.

Charles, M. P. (1984). Introductory Remarks on the Cereals. *Bulletin on Sumerain Agriculture*, 1, 17-31.

Charles, M. P. (1990). Traditional Crop Husbandry in Southern Iraq. *Bulletin on Sumerian Agriculture*, 5, 47-64.

Chatterton, B. A. and Chatterton, L. (1984). *Medicago* - its Possible Role in Romano-Libyan Farming and its Positive Role in Modern Dry Farming. *Libyan Studies*, 14, 157-160.

Chatterton, B. A. and Chatterton, L. (1986). A Hypothetical Answer to the Decline of the Granary of Rome. *Libyan Studies*, 16, 95-99.

Clifford, J. (1986). Introduction: Partial Truths. In J. Clifford and G. E. Marcus (eds.) *Writing Culture. The Poetics and Politics of Ethnography.* University of California Press, Berkeley and Los Angeles. 1-26.

Commander, S. and Burgess, S. (1990). Labour Markets in North Africa and the Near East: a Survey of Developments since 1970. In D. Tully (ed.) *Labour and Rainfed Agriculture in West Asia and North Africa.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 25-47.

Cooper, P. J. M. and Gregory, P. J. (1987). Soil Water Management in the Rain-Fed Farming Systems of the Mediterranean Region. *Soil Use and Management* 3, (2), 57-62.

Cooper, P. J. M. (1991). Fertiliser Use, Crop Growth, Water use and WUE in Mediterranean Rainfed Farming Systems. In H. C. Harris, P. J. M. Cooper and M. Pala (eds.) Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas. ICARDA, Aleppo, Syria. 135-152.

Cuinet, V. (1896). *Syrie, Liban et Palestine: Géographie Administrative, Statistique et Raisonnee*. Ernest Leroux, Paris.

Dagnelie, P. (1973). L'Analyse Factorielle. In R. H. Whittaker (ed.) *Ordination and Classification of Plant Communities*. Dr. Junk Publishers, The Hague. 223-248.

Dahl, G. and A. Hjort (1976). *Having Herds: Pastoral Herd Growth and Household Economy*. Dept. of Social Anthropology, University of Stockholm, Stockholm.

Dalman, G. (1932). *Arbeit und Sitte in Palästina*, Band II: *Der Ackerbau*. C. Bertelsmann, Gütersloh, Germany.

Dalman, G. (1933). *Arbeit und Sitte in Palästina*, Band III: *Von der Ernte zum Mehl*. C. Bertelsmann, Gütersloh, Germany.

Davis, P. H. (1965-1988). *Flora of Turkey and the East Aegean Islands*. 10 Vols.. Edinburgh University Press, Edinburgh.

Davis, J. (1991). Contributions to a Mediterranean Rural Archaeology: Historical Case Studies from the Ottoman Cyclades. *Journal of Mediterranean Archaeology*, 4 (2), 131-216.

Dennell, R. W. (1974). Botanical Evidence for Prehistoric Crop Processing Activities. *Journal of Archaeological Science*, 1, 275-284.

Dennett, M. D. (1987). Variation in Rainfall- the Background to Soil and Water Management in Dryland Regions. *Soil Use and Management*, 3 (2), 47-51.

Dixon, J. A., James, D. E. and Sherman, P. B. (1989). *The Economics of Dryland Management*. Earthscan Publications Ltd., London.

Doorenbos, J. and Pruitt, W. O. (1977). *Crop Water Requirements*. Irrigation and Drainage Paper No. 24. FAO, Rome.

Doorenbos, J. and Kassam, A. H. (1979). *Yield Response to Water*. Irrigation and Drainage Paper No. 33. FAO, Rome.

Duwayri, M. (1985). Farm Systems in Rain-Fed Areas. In A. B. Zahlan (ed.) *The Agricultural Sector of Jordan: Policy and Systems Studies*. Published for the Abdul Hameed Shoman Foundation, Amman by Ithaca Press, London. 126-158.

Eickelman, D. (1981). *The Middle East: an Anthropological Approach*. Prentice-Hall, New Jersey.

Eig, A. (1933). A Historical-Phytosociological Essay on Palestinian Forests of *Quercus aegilops* L. ssp. *ithaburensis* (Desc.) in Past and Present. *Beihefte zum Botanischen Zentralblatt*, 51, 225-272.

Eig, A. (1938). On the Phytogeographical Sub-division of Palestine. *Palestine Journal of Botany Jerusalem*, 1, 4-12.

Eig, A. (1946). Synopsis of the Phytosociological Units of Palestine. *Palestine Journal of Botany*, 3 (4), 182-248.

al-Eisawi, D. M. (1982). List of Jordan Vascular Plants. *Mitteilungen der Botanischen Staatssammlun Muenchen*, 18, 79-182.

al-Eisawi, D. M. (1985). Vegetation in Jordan. In A. Hadidi (ed.) *Studies in the History and Archaeology of Jordan II*. Department of Antiquites, Amman, Hashemite Kingdom of Jordan, 45-57.

Elezari-Volcani, I. (1930). *The Fellah's Farm.* Jewish Agency for Palestine, Tel-Aviv.

Ellenberg, H. (1950). *Landwirtschaftliche Pflanzensoziologie I: Unkrautgemeinschaften als Zeiger für Klima und Boden.* Ulmer, Stuttgart/Ludwigsburg.

Ellenberg, H. (1979). Zeigerwerte der Gefässpflanzen Mitteleuropas. *Scripta Geobotanica,* 9, Göttingen (second edition). 1-122.

Ellis, F. (1988). *Peasant Economics. Farm Households and Agrarian Development.* Cambridge, Cambridge University Press.

Emberger, L. (1955). Afrique du Nord-Ouest. In *Reserches sur la Zone Aride, II. Ecologie Végétate,* Compte rendu de Reserches. UNESCO, Paris.

FAO (1971). *Land Degradation.* FAO Soils Bulletin No. 13. FAO, Rome.

FAO (1982). *Organic Materials and Soil Productivity in the Near East.* FAO Soils Bulletin No. 45. FAO, Rome.

FAO (1991). *Traditional Foods in the Near East.* FAO Food and Nutrition Paper 50. FAO, Rome.

FAO-UNESCO (1974). *Soil Map of the World. Vol. 1 - Legend.* FAO-UNESCO, Paris.

Feinbrun, N. and Zohary, M. (1955). A Geobotanical Survey of TransJordan. *Bulletin of the Research Council of Israel,* 5 (D), 5-28.

Firestone, Y. (1981). Land Equalisation and Factor Scarcities: Holding Size and the Burden of Impositions in Imperial Central Russia and the Late Ottoman Levant. *Journal of Economic History,* 41 (4), 813-833.

Firestone, Y. (1990). The Land Equalizing Musha' Village: a Reassessment. In G. G. Gilbar (ed.) *Ottoman Palestine 1800-1914.* E. J. Brill, Leiden. 91-129.

Fischbach, M. R. (1990). Observations and Land Ownership in Liwa' 'Ajlun during the Mandate. *Al-Nadwan,* 2 (3), 26-30.

FitzPatrick, E. A. (1983). *Soils. Their Formation, Classification and Distribution.* London, Longman.

Fleming, A. (1985). Land Tenure, Productivity and Field Systems. In G. Barker and C. Gamble (eds.) *Beyond Domestication in Prehistoric Europe.* Academic Press, London. 125-145.

Forbes, F. A. (1976). 'The Thrice-Ploughed Field': Cultivation Techniques in Ancient and Modern Greece. *Expedition,* 19 (i), 5-11.

Forbes, H. A. (1976). 'We Have a Little of Everything': the Ecological Basis of Some Agricultural Practices in Methana, Trizinia. *Annals of the New York Academy of Sciences* 268, 236-50.

Forbes, H. A. (1982). *Strategies and Soils: Technology, Production and Envrionment in the Peninsula of Methana, Greece.* PhD thesis, University of Pensylvania.

Forbes, H. A. (1989). Of Grandfathers and Grand Theories: the Hierarchised Ordering of Responses to Hazard in a Greek Rural Community. In P. Halstead and J. O'Shea (eds.) *Bad Year Economics: Cultural Responses to Risk and Uncertainty.* Cambridge University Press, Cambridge. 87-97.

French, R. J. (1963a). New Facts about Fallowing, Part 1. *Journal of Agriculture*, 67, 42-48.

French, R. J. (1963b). New Facts about Fallowing, Part 2. *Journal of Agriculture*, 67, 76-79.

Friedmann, H. (1980). Household Production and the National Economy: Concepts for the Analysis of Agrarian Formations. *Journal of Peasant Studies*, 7 (2), 158-184.

Froud-Williams, R. J., Chancellor, R. J. and Drennan, D. S. H. (1981). Potential Changes in Weed Floras Associated with Reduced-Cultivation Systems for Cereal Production in Temperate Regions. *Weed Research*, 21, 99-109.

Fuller, A. H. (1961). *Buarij, Portrait of a Lebanese Muslim Village*. Harvard Middle Eastern Monographs, 6. Harvard University Press, Cambridge.

Gale, S. J. and P. G. Hoare (1991). *Quaternary Sediments*. New York, Belhaven Press.

Gauch, H. G. (1982). *Multivariate Analysis in Community Ecology*. Cambridge University Press, Cambridge.

Geertz, C. (1963). *Agricultural Involution*. Berkeley, University of California Press.

Gerber, H. (1987). *The Social Origins of the Modern Middle East*. Boulder, Colerado, Lynne Rienner Publishers.

Ghannam, F. (1990). Rumaimin. In M. Mundy and R. S. Smith (eds.) *Part-Time Farming. Agricultural Development in the Zarqa River Basin, Jordan*. Institute of Archaeology and Anthropology, Yarmouk University, Irbid, Jordan. 113-160.

Glavanis, K. and Glavanis, P. (1983). The Sociology of Agrarian Relations in the Middle East: the Persistence of Household Production. *Current Sociology*, 31 (2), 1-109.

Glavanis, K. and Glavanis, P. (1990). Introduction. In K. Glavanis and P. Glavanis (eds.) *The Rural Middle East. Peasant Lives and Modes of Production*. Zed Books Ltd. and Birzeit University, London. 1-32.

Godwin, R. J. (1990). Agricultural Engineering in Development: Tillage for Crop Production in Areas of Low Rainfall. FAO Agricultural Services Bulletin, 83. FAO, Rome.

Goody, J. (1976). *Production and Reproduction. A Comparative Study of the Domestic Domain*. Cambridge, Cambridge University Press.

Gregory, P. J. (1991). Concepts of Water Use Efficiency. In H. C. Harris, P. J. M. Cooper, M. Pala, (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas*. ICARDA, Ankara, Turkey. 9-20.

Grigg, E. C. (1974). *The Agricultural Systems of the World: an Evolutionary Approach*. Cambridge University Press, Cambridge.

Guler, M., Durutan, N., Karaca, M., Avci, M., and Eyboglu, H. (1991). Increasing Water Use Efficiency through Fallow Soil Management under Central Anatolian Conditions. In H. C. Harris, P. J. M. Cooper and M. Pala (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas*. ICARDA, Aleppo, Syria. 76-83.

Håckansson, S. (1982) Multiplication, Growth and Persistence of Perennial Weeds. In W. Holzner and N. Numata (eds.) Biology and Ecology of Weeds. Dr. Junk Publishers, The Hague. 123-135.

Haddad, N. I. (1983a) Effect of Date of Planting and Plant Population on the Yield of Chickpeas (*Cicer arietinum* L.) in Jordan. *Dirasat* 10 (1), 117-128.

Haddad, N. I. (1983b) Effect of Date of Planting and Plant Population on Yield and Other Agronomic Characteristics of Lentil (*Lens culinaris* Medic.). *Dirasat*, 10 (1), 153-167.

Haddad, N. I. and Snobar, B. A. (1990). The Role of Legumes in the Farming Systems of Jordan. In A. E. Osman, M. H. Ibrahim and M. A. Jones (eds.) *The Role of Legumes in the Farming Systems of the Mediterranean Areas.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 77-83.

Halstead, P. (1987). Traditional and Ancient Rural Economy in Mediterranean Europe: Plus ça Change? *Journal of Hellenic Studies*, 107, 77-87.

Halstead, P. (1989). The Economy has a Normal Surplus: Economic Stability and Social Change among Early Farming Communities of Thessaly, Greece. In P. Halstead and J. O'Shea (eds.) *Bad Year Economics: Cultural Responses to Risk and Uncertainty.* Cambridge University Press, Cambridge. 68-80.

Halstead, P. (1990). Quantifying Sumerian Agriculture - Some Seeds of Doubt and Hope. *Bulletin on Sumerian Agriculture*, 5, 187-195.

Halstead, P. (1992a). Agriculture in the Bronze Age Aegean. Towards a Model of Palatial Economy. In B. Wells (ed.) *Agriculture in Ancient Greece.* Paul Åströms Förlag, Stockholm. 105-117.

Halstead, P. (1992b) The Mycenaean Palatial Economy: Making the Most of the Gaps in the Evidence. *Proceedings of the Cambridge Philological Society*, 38, 57-86.

Halstead, P. and Jones, G. (1989). Agrarian Ecology in the Greek Islands: Time Stress, Scale and Risk. *Journal of Hellenic Studies*, 109, 41-55.

Halstead, P. and O'Shea J. (1989). *Bad Year Economics: Cultural Responses to Risk and Uncertainty.* Cambridge University Press, Cambridge.

Hamarneh, M. B. (1985). *Social and Economic Transformation of Trans-Jordan, 1921-46.* PhD Thesis, Georgetown University.

Harris, H. C. (1989). Productivity of Crop Rotations. Farm Resource Management Program: Annual Report 1989. Aleppo, Syria, ICARDA, 137-166.

Harris, H. C. (1991). Implications of Climatic Variability. In H. C. Harris, P. J. M. Cooper and M. Pala (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas.* ICARDA, Aleppo, Syria. 21-34.

Harris, H. C., Osman, A. E., Cooper, P. J. M., and Jones, M. J. (1991). The Management of Crop Rotation for Greater Water Use Efficiency under Rainfed Conditions. In H. C. Harris, P. J. M. Cooper and M. Pala (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas.* ICARDA, Aleppo, Syria. 237-250.

Harriss, J. (1982). General Introduction. In J. Harriss (ed.) *Rural Development. Theories of Peasant Economy and Agrarian Change.* Routledge, London. 15-34.

Harvey, J. A. (1980). Summer Crops in Syria. Discussion Paper. ICARDA, Aleppo, Syria.

Helburn, N. (1955). A Stereotype of Agriculture in Semiarid Turkey. *Geographical Review*, 45, 375-84.

Henderson, D. W. (1979). Soil Management in Semi-Arid Environments. In A. E. Hall, G. H. Cannell and H. W. Lawton (eds.) *Agriculture in Semi-Arid Environments*. Springer Verlag, Berlin. 224-237.

Hill, M. O. (1979). *DECORANA - A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging*. Ithaca, New York, Cornell University.

Hillman, G. C. (1973a). Crop Husbandry and Food Production: Modern Basis for the Interpretation of Plant Remains. *Anatolian Studies*, 23, 241-244.

Hillman, G. C. (1973b). Agricultural Productivity and Past Population Potential at Asvan. *Anatolian Studies*, 23, 225-40.

Hillman, G. C (1981). Reconstructing Crop Husbandry Practices from Charred Remains of Crops. In R. Mercer (ed.) *Farming Practice in British Prehistory*. Edinburgh University Press, Edinburgh. 123-162.

Hillman, G. C. (1984a). Interpretation of Archaeological Plant Remains: the Application of Ethnographic Models from Turkey. In W. van Zeist and W. A. Casparie (eds.) *Plants and Ancient Man*. Balkema, Rotterdam. 1-41.

Hillman, G. C. (1984b). Traditional Husbandry and Processing of Archaic Cereals in Recent Times: the Operations, Products and Equipment which Might Feature in Sumerian Texts. Part 1: The Glume Wheats. *Bulletin on Sumerian Agriculture*, 1, 114-152.

Hillman, G. C. (1985). Traditional Husbandry and Processing of Archaic Cereals in Recent Times: the Operations, Products and Equipment that Might Feature in Sumerian Texts. Part II: The Free-Threshing Cereals. *Bulletin on Sumerian Agriculture*; 2, 1-31.

Hillman, G. C. (1991). Phytosociology and Ancient Weed Floras: Taking Account of Taphonomy and Changes in Cultivation Methods. In D. R. Harris and K. D. Thomas (eds.) *Modelling Ecological Change: Perspectives from Neoecology, Palaeoecology and Environmental Ecology*. Institute of Archaeology, London. 27-40.

Hodder, I. (1982). *The Present Past: an Introduction to Anthropology for Archaeologists*. Batsford, London.

Hodder, I. (1990). *The Domestication of Europe. Structure and Contingency in Neolithic Societies*. Blackwell, Oxford.

Holzner, W. (1978). Weed Species and Weed Communities. *Vegetatio*, 38 (1), 13-20.

Holzner, W. (1982). Weeds as Indicators. In W. Holzner and N. Numata (eds.) *Biology and Ecology of Weeds*. Dr. Junk Publishers, The Hague. 187-190.

Holzner, W., Hayashi, I. and Glauninger, J. (1982). Reproductive Strategy of Annual Agrestals. In W. Holzner and N. Numata (eds.) *Biology and Ecology of Weeds*. Dr. Junk Publishers, The Hague. 111-121.

Hopfen, H. J. (1969). *Farm Implements for Arid and Tropical Regions.* Agricultural Development Paper No. 91. FAO, Rome.

Houérou, H. N. L (1973). Fire and Vegetation in the Mediterranean Basin. *Proceedings of the Tall Timbers Fire Ecology Conference*, 13, 237-77.

Houérou, H. N. L (1981). Impact of Man and his Animals on Mediterranean Vegetation. In F. di Castri, D. W. Goodall and R. L Specht (eds.) *Mediterranean-Type Shrublands.* Ecosystems of the World 11. Elsevier Scientific Publishing Co., Amsterdam. 479-521.

Hubbard, C. E. (1984). *Grasses. A Guide to their Structure, Identification, Uses and Distribution in the British Isles.* Revised by J. C. E. Hubbard. Middlesex, Penguin Books.

Hubbard, R. N. L B. and al-Azm, A. A. (1990). Quantifying Preservation and Distortion in Carbonised Seeds: and Investigating the History of Friké Production. *Journal of Archaeological Science*, 17 (1), 103-106.

Hunter, B. (1994). Jordan. In *The Statesman's Yearbook. Statistical and Historical Annual of the States of the World for the Year 1994-95.* Macmillan Press Ltd., London. 830-834.

Hunting Technical Services Ltd. (1956). *Report on the Range Classification Survey of the Hashemite Kngdom of Jordan.* Hunting Technical Services Ltd., Elstree, Hertfordshire.

el-Hurani, M. H. (1985). The Supply of Agricultural Labour. In A. B. Zahlan and S. Qasem (eds.) *The Agricultural Sector of Jordan: Policy and Systems Studies.* Published for the Abdul Hameed Shoman Foundation, Amman by Ithaca Press, London. 68-87.

el-Hurani, M. H. (1989). Analysis of Agricultural Policy in the Jordan Drylands. In C. E. Whitman, J. F. Parr, R. I. Papendick, and R. E. Meyer (eds.) *Soil, Water, and Crop/Livestock Management Systems for Rainfed Agriculture in the Near East Region.* USDA/USAID/ICARDA, Washington. 36-56.

el-Hurani, M. H. (1988). *Report on the Wheat Baseline Data Survey.* Jordan Highland Agricultural Development Project, Publication No. 10, Amman, Jordan.

el-Hurani, M. H. and Duwayri, M. (1986). Policies Affecting Field Crop Production in the Rainfed Sector. In A. Burrell (ed.) *Agricultural Policy in Jordan.* London, Ithaca Press, 55-72.

Hütteroth, W.-D. and Abdulfattah, K. (1977). *Historical Geography of Palestine, Transjordan and Southern Syria in the Late 16th Century.* Erlanger Geographische Arbeiten, Erlangen.

ICARDA (1984). *Cereal Improvement in Dry Areas: A Report on the Jordan Co-Operative Cereal Improvement Project 1978-79 to 1982-83.* ICARDA, Aleppo, Syria.

Ionides, M. G. and G. S. Blake (1939). *Report on the Water Resources of Transjordan and their Development: Incorporating a Report on Geology, Soils and Minerals and Hydrogeological Correlations.* Crown Agents for the Colonies, London.

Issawi, C. (1988). *The Fertile Crescent, 1800-1914.* Oxford University Press, Oxford.

Janssen, B. H. (1972). The Significance of the Fallow Year in the Dry-Farming System of the Great Konya Basin, Turkey. *Netherlands Journal of Agricultural Science*, 20, 247-260.

Jaradat, A. A. (1988a). Tillage Practices. In Jaradat A. A. (ed.) *An Assessment of Research Needs and Priorities for Rainfed Agriculture.* The United States Agency for International Development, Jordan. 208-242.

Jaradat, A. A. (1988b). Crop Rotations. In Jaradat, A. A. (ed.) *An Assessment of Research Needs and Priorities for Rainfed Agriculture.* Jordan, The United States Agency for International Development, 280-310.

Jaradat, A. A. (1988b). Crop Rotations. In Jaradat, A. A. (ed.) *An Assessment of Research Needs and Priorities for Rainfed Agriculture.* The United States Agency for International Development, Jordan. 244-278.

Jaradat, A. A. (1988d) Soil Fertility. In Jaradat, A. A. (ed.) *An Assessment of Research Needs and Priorities for Rainfed Agriculture.* The United States Agency for International Development, Jordan. 156-205.

Jaubert, R. and Oglah, M. (1985). *Farming Systems Management in the Bueda/Breda Subarea.* Research Report. ICARDA, Aleppo, Syria.

Jones, G. E. M. (1983a). The Ethnoarchaeology of Crop Processing: Seeds of a Middle Range Methodology. *Archaeological Review from Cambridge*, 2 (2), 17-26.

Jones, G. E. M. (1983b). *The Use of Ethnographic and Ecological Models in the Interpretation of Archaeological Plant Remains: Case Studies from Greece.* PhD Thesis, University of Cambridge.

Jones, G. E. M. (1984). Interpretation of Archaeological Plant Remains: Ethnographic Models from Greece. In W. van Zeist and W. A. Casparie (eds.) *Plants and Ancient Man.* Balkema, Rotterdam. 43-61.

Jones, G. E. M. (1989). A Statistical Approach to the Archaeological Identification of Crop Processing. *Journal of Archaeological Science* 14, 311-323.

Jones, G. E. M. (1991). Numerical Analysis in Archaeobotany. In W. van Zeist, K. Wasylikowa and K.-E. Behre (eds.) *Progress in Old World Palaeoethnobotany.* A. Balkema, Rotterdam. 63-78.

Jones, G. E. M. (1992). Weed Phytosociology and Crop Husbandry: Identifying a Contrast between Ancient and Modern Practice. In J. P. Pals, J. Burman and M. van der Veen (eds.), Festschrift for Professor van Zeist *Review of Palaeobotany and Palynology*, 73, 133-143.

Jones, G., Charles M., Colledge S., and Halstead, P. (in press). Towards the Archaeobotanical Recognition of Winter-Cereal Irrigation: an Investigation of Modern Weed Ecology in Northern Spain.

Jones, M. J. (1990). The Role of Forage Legumes in Rotation with Cereals in Mediterranean Areas. In A. E. Osman, M. H. Ibrahim and M. A. Jones (eds.) *The Role of Legumes in the Farming Systems of the Mediterranean Areas.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 195-203.

Jones, M. K. (1984). *The Ecological and Cultural Implications of Carbonised Seed Assemblages from Selected Archaeological Contexts in Southern Britain.* DPhil Thesis, University of Oxford.

Jones, M. K. (1988). The Arable Field: a Botanical Battleground. In M. K. Jones (ed.) *Archaeology and the Flora of the British Isles.* Oxford University Committee for Archaeology, Oxford, Monograph No. 14. 86-92.

Jongman, R. H. G., Braak, C. J. ter and Tongeren, O. F. R. van (1987). *Data Analysis in Community and Landscape Ecology.* Pudoc, Wageningen.

Jordan, L. S. and Shaner, D. L. (1979). Weed Control. In A. E. Hall, G. H. Cannell and H. W. Lawton (eds.) *Agriculture in Semi-Arid Environments.* Springer Verlag, Berlin. 226-296.

Kadereit, J. W. (1988). A Revision of *Papaver* L. Section *Rhoeadium* Spach. *Notes of the Royal Botanic Gardens at Edinburgh,* 45 (2), 225-286.

Karablieh, E. M. and Salem, M. A. (1990). The Impact of Technology on Employment in the Rainfed Farming Areas of Irbid District, Jordan. In D. Tully (ed.) *Labour, Employment and Agricultural Development in West Asia and North Africa.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 7-30.

Karim, F. M. and Quraan, S. A. (1987). *Wild Flowers of Jordan.* Yarmouk University, Irbid, Jordan,.

Kassam, A. H. (1981). Climate, Soil and Land Resources in North Africa and West Asia. *Plant Soil,* 58, 1-29.

Keatinge, J. D. H. (1985). The Influence of Precipitaion Regime on the Management of Three-course Crop Rotations in Northern Syria. *Journal of Agricultural Science, Cambridge,* 104, 281-287.

Keen, B. A. (1946). *The Agricultural Development of the Middle East.* His Majesty's Stationery Office, London.

Keyder, Ç. (1983). Paths of Rural Transformation in Turkey. *Journal of Peasant Studies,* 11 (1), 34-49.

Keyder, Ç. and Tabak, F. (1991). *Landholding and Commercial Agriculture in the Middle East.* State University of New York Press, Albany.

Konikoff, A. (1943). *Trans-Jordan: An Economic Survey.* Jewish Agency for Palestine, Jerusalem.

Kornas, J. (1988). Speirochore Ackerwildkrauter: von okologischer Speciziaiserung zum Aussterben. *Flora,* 180, 83-91.

Lancaster W. and Lancaster, F. (1991). Limitations on Sheep and Goat Herding in the Eastern Badia of Jordan: An Ethno-archaeological Enquiry. *Levant,* 23, 125-138.

Lange, A. G. (1990). *De Horden near Wijk bij Duurstede. Plant Remains from a Native Settlement at the Roman Frontier: a Numerical Approach.* Amersfoort, Rijksdienst voor het Oudheidkundig Bodemonderzoek.

Latron, A. (1936). *La Vie Rurale en Syrie et au Liban.* Mémoires de L'Institut Français de Damas, Beirut.

Lazendorfer, M. (1985). Agricultural Mechanisation in Jordan. A Study of its Progress in a Socio-economic Context. Socioeconomic Studies on Rural Development, vol. 62. Edition Heredot, Gottingen.

Lewis, N. N. (1987). *Nomads and Settlers in Syria and Jordan, 1800-1980.* Cambridge University Press, Cambridge.

Lindstrom, M. J., Koehler, F. E. and Papendick, R. I. (1974). Tillage Effects on Fallow Water Stroage in the Eastern Washington Dryland Region. *Agronomy Journal,* 66, 312-316.

Littlejohn, L. (1946). Some Aspects of Soil Fertility in Cyprus. *Empire Journal of Experimental Agriculture,* 14, 123-134.

Loizides, P. A. (1948). The Cereal-Fallow Rotation in Cyprus. In Proceedings of the First Commonwealth Conference on Tropical and Subtropical Soils. Commonwealth Bureau of Soil Sciences, Harpenden, Technical Communication No. 46. 210-217.

Loizides, P. A. (1958). Fertilizer Experiments in Cyprus: I. The Cereals. *Empire Journal of Experimental Agriculture,* 26, 229-246.

Long, G. (1957). *The Bioclimatology and Vegetation of East Jordan.* UNESCO/FAO, Rome.

Mabberly, D. J. (1987). *A Portable Dictionary of the Higher Plants.* Cambridge Univeristy Press, Cambridge.

Maekawa, K. (1984). Cereal Cultivation in the Ur III Period. *Bulletin on Sumerian Agriculture,* 1, 73-96.

Merrill, S. (1881). *East of the Jordan: A Record of Travel and Observation in the Countries of Moab, Gilead and Bashan during the years 1875-1877.* Charles Scribner's Sons, New York.

Mendel, K., Kirkby, E. A. (1978). *Principles of Plant Nutrition.* International Potash Institute, Berne.

Meteorological Department, The Hashemite Kingdom of Jordan (1988). *Jordan Climatological Data Handbook.* The Hashemite Kingdom of Jordan Meteorological Department, Amman.

Mintz, S. W. (1974). A Note on the Definitions of Peasantries. *Journal of Peasant Studies,* 1 (3), 91-106.

Mitchell, C. W. and J. A. Howard (1978). *Land System Classification. A Case History: Jordan.* FAO, Rome.

Mundy, M. (1990). Introduction. In M. Mundy and R. S. Smith (eds.) *Part-Time Farming. Agricultural Development in the Zarqa River Basin, Jordan.* Institute of Archaeology and Anthropology, Yarmouk University, Irbid, Jordan. 1-12.

Mundy, M. (1990). Conclusion. In M. Mundy and R. S. Smith (eds.) *Part-Time Farming. Agricultural Development in the Zarqa River Basin, Jordan.* Institute of Archaeology and Anthropology, Yarmouk University, Irbid, Jordan. 161-173.

Mundy, M. (1992). Shareholders and the State: Representing the Village in the Late 19th Century Registers of the Southern Hawran. In T. Philipp (ed.) *The Syrian Land in the 18th and 19th Century.* Berliner Islamstudien, Bd. 5. Franz Steiner Verlag, Stuttgart.

Mundy, M. and Smith, R. S. (1990). *Part-Time Farming. Agricultural Development in the Zarqa River Basin, Jordan.* Institute of Archaeology and Anthropology, Yarmouk University, Irbid, Jordan.

Nahal, I. (1981). The Mediterranean Climate from a Biological Viewpoint. In F. di Castri, D. W. Goodall and R. L. Specht (eds.) *Mediterranean-Type Shrublands.* Ecosystems of the World 11. Elsevier Scientific Publishing Company, Amsterdam. 63-86.

Naveh, Z. (1973). The Ecology of Fire in Israel. *Proceedings of the Tall Timbers Fire Ecology Conference,* 13, 131-170.

Naveh, Z. (1975). The Evolutionary Significance of Fire in the Mediterranean Region. *Vegetatio,* 29 (3), 199-208.

Naveh, Z. (1990). Ancient Man's Impact on the Mediterranean Landscape in Israel - Ecological and Evolutionary Perspectives. In S. Bottema, G. Entjes-Nieborg and W. van Zeist (eds.) *Man's Role in the Shaping of the Eastern Mediterranean Landscape.* A. A. Balkema, Rotterdam.

Neil, J. (1890). Land Tenure in Ancient Times as Preserved by the Present Village Communities in Palestine. *Journal of the Transactions of the Victoria Institute,* 24, 155-203.

Nordblom, T. L. (1987). Farming Pracitices in Southern Idleb Province, Syria: 1985 Survey Results. Research Report. ICARDA, Aleppo, Syria.

Oliphant, L. (1881). *The Land of Gilead, with Excusions in the Lebanon.* Appleton and Co., New York.

Osman, A. E., Ibrahim, M. H. and Jones, M. A. (1990). *The Role of Legumes in the Farming Systems of the Mediterranean Areas* (Proceedings of a Workshop UNDP/ICARDA, Tunis, June 20-24, 1988). Kluwer (Academic Publishers for ICARDA), Dordrecht.

Pala, M. (1991). The Effect of Crop Management on Increased Production through Improved Water Use Efficiency at Sowing. In H. C. Harris, P. J. M. Cooper and M. Pala (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed.* ICARDA, Aleppo, Syria. 87-105.

Palmer, C. and Russell, K. W. (1993). Traditional Ards of Jordan. *Annual of the Department of Antiquities of Jordan,* 37, 37-53.

Papastylianou, I. (1988). The Role of Legumes in Agricultural Production in Cyprus. In D. P. Beck and L. A. Materon (eds.) *Nitrogen Fixation by Legumes in Mediterranean Agriculture.* Kluwer (Academic Publishers for ICARDA, Dordrecht). 55-63.

Papastylianou, I. (1990). The Role of Legumes in the Farming Systems of Cyprus. In A. E. Osman, M. H. Ibrahim and M. A. Jones (eds.) *The Role of Legumes in the Farming systems of the Mediterranean Areas.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 39-49.

Papastylianou, I. (1991). Land and Rainfall Use Efficiency and Nitrogen Balance of Rotation Systems under Rainfed Conditions in Cyprus. In H. C. Harris, P. J. M. Cooper and M. Pala (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas.* ICARDA, Aleppo, Syria. 260-266.

Papendick, R. I. (1989). Storage and Retension of Water During Fallow. In C. E. Whitman, J. F. Parr, R. I Papendick and R. E. Meyer (eds.) *Soil, Water, and Crop/Livestock Management Systems for Rainfed Agriculture in the Near East Region.* USDA/USAID, Washington. 260-269.

Papendick, R. I., Parr, J. F., and Meyer, R. E. (1991). Tillage and Stubble Management: On-going Research in the USA. In H. M. Harris, P. J. M. Cooper and M. Pala (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas.* ICARDA, Aleppo, Syria. 66-75.

Patai, R. (1949). Musha'a Tenure and Co-Operation in Palestine. *American Anthropologist,* 51, 436-445.

Percival, J. (1921). *The Wheat Plant.* Duckworth and Co., London.

Pinner L. (1930). Wheat Culture in Palestine. *Bulletin of The Palestine Economic Society,* 5 (2).

Pons, A. and P. Quézel (1985). The History of the Flora and Vegetation and Past and Present Human Disturbance in the Mediterranean Region. In C. Gómez-Campo (ed.) *Plant Conservation in the Mediterranean Area* (Geobotany 7). Dr W. Junk, Dordrecht.

Post, G. E. (1883-1896). *Flora of Syria, Palestine and Sinai.* Beirut, The American Press; 2nd edition by J. E. Dinsmore (1932-1933) 2 vols.. Beirut, Beirut American University Publications Faculty of Arts and Sciences, Natural Science Series.

Qasem, S. (1985). Agricultural Research and Extension. In A. B. Zahlan (ed.) *The Agricultural Sector of Jordan: Policy and Systems Studies.* Published for the Abdul Hameed Shoman Foundation, Amman by Ithaca Press, London. 343-411.

Qasem, S. and Mitchell, M. (1986). The Problems of Rainfed Agriculture. In A. Burrell (ed.) Agricultural Policy in Jordan. Ithaca Press, London. 30-40.

Qudah, B. H. and Jaradat, A.A. (1988). Soil Resources. In A. A. Jaradat (ed.) *An Assessment of Research Needs and Priorites for Rainfed Agriculture in Jordan.* USAID, Jordan. 65-114.

Quennell, A. M. (1951). The Geology and Mineral Resources of (former) Transjordan. *Colonial Geological and Mineral Resources,* 2 (2), 85-115. (Map at 1:500 000).

Rabinovitch-Vin, A. (1983). Influence of Nutrients on the Composition and Distribution of Plant Communities in Mediterranean-Type Ecosystems of Israel. In K. J. Kruger, D. T. Mitchell and J. U. M. Jarvis (eds.) *Mediterranean-Type Ecosystems: the Role of Nutrients.* Ecological Studies 43. Springer Verlag, Berlin. 74-85.

Rackham, O. (1982). Land-use and the Native Vegetation of Greece. In M. Bell and S. Limbrey (eds.) *Archaeological Aspects of Woodland Ecology.* BAR International Series 146, Oxford. 177-198.

Ramussen, P. E., Allmaras, R. R., Rohde, C. R., and Roager, N. C. Jnr. (1980). Crop Residue Influences on Soil Carbon and nitrogen in a Wheat-Fallow System. *Soil Science Society of America Journal,* 45, 596-600.

Rassam, A. and Tully, D. (1986). Gender Related Aspects of Agricultural Labour in Northwestern Syria. Discussion Paper No. 20. ICARDA, Aleppo, Syria.

Richards, A. and Ramezani, A. (1990). Mechanisation, Off-Farm Employment and Agriculture. In D. Tully (ed.) *Labour and Rainfed Agriculture in West Asia and North Africa.* Kluwer (Academic Publishers for ICARDA), Dordrecht. 49-66.

Robinson, E. and Smith, A. (1856). *Biblical Researches in Palestine, Mount Sinai and Arabia Petrea; a Journey of Travels in the Year 1838.* Crocker & Brewster, Cambridge, Mass..

Rogan, E. L. (1991). *Incorporating the Periphery: The Ottoman Extension of Direct Rule Over Southeastern Syria (Transjordan) 1867-1914.* PhD Thesis, Harvard University.

Rogers, B. (1980). *The Domestication of Women.* London and New York, Routledge.

Rowntree, D. (1981). *Statistics without Tears. A Primer for Non-mathematicians.* Penguin, London.

Russell, K. W. (1988). *After Eden: the Behavioural Ecology of Early Food Production in the Near East and North Africa.* BAR International Series 391, Oxford.

Sach, F. (1968). Proposal for the Classification of Pre-industrial Tilling Implements. *Tools and Tillage,* 1:3-27.

Saimeh, M. H. and Battikhi, A, M. (1985). Replenishment and Depletion of Soil Moisture in the Northern Rainfed Areas of Eastern Jordan I - Soil series 11. *Dirasat,* 12 (6), 67-86.

Salim, M. H. (1961). *Investigations on Improvement of Wheat and Barley Production in Jordan 1952-1960.* Ministry of Agriculture, Amman, Jordan.

Saxena, M. C. (1981). Agronomy of Lentils. In C. Webb and G. Hawtin (eds.) *Lentils.* UK, CAB/ICARDA, Wallingford. 111-129.

Saxena, M. C. (1987). Agronomy of the Chickpea. In M. C. Saxena and K. B. Singh (eds.) *The Chickpea.* CAB/ICARDA, Wallingford, UK. 207-232.

Saxena, M. C. (1988). Food Legumes in the Mediterranean Type Environment and ICARDA's Efforts in Improving their Productivity. In D. P. Beck and L. A. Materon (eds.) *Nitrogen Fixation by Legumes in Mediterranean Agriculture.* Developments in Plant and Soil Sciences, vol. 32. Kluwer (Academic Publishers for ICARDA), Dordrecht. 11-23.

Schoonhoven, A. van (1991). Soil and Crop Managment for Improved Water Use Efficiency in Dry Areas: the Challenge. In H. C. Harris, P. J. M. Cooper and M. Pala (eds.) *Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas.* ICARDA, Aleppo, Syria. 3-8.

Schumacher, G. (1889). *Across the Jordan: Being an Exploration and survey of parts of Hauran and Jaulan.* Alexander Watt, London.

Schumacher, G. (1890). *Northern 'Ajlun, 'Within the Decapolis'.* Alexander Watt, London.

Seccombe, I. (1984). *Jordan.* World Bibliographical Series, Vol. 55. Clio Press, Oxford and Santa Barbara.

Seccombe, I. (1987). Labour Migration and the Transformation of a Village Economy: a Case Study form North-west Jordan. In R. I. Lawless *The Middle Eastern Village: Changing Economic and Social Relations.* Croom Helm, Beckenham, Kent. 115-145.

Seetzen, V. J. (1854-1959). *Reisen durch Syrien, Palästina, Phönicien, die Tranjordan-Lander, Arabea Petraea und Unter-Aegypten.* Fr. Kruse, Berlin.

Semple, E. C. (1932). *The Geography of the Mediterranean Refion and its Relation to Ancient History.* Constable & Co. Ltd., London.

Simpson, J. H. (1930). *Palestine: Report on Immigration, Land Settlement and Development.* Great Britain Colonial Office. His Majesty's Stationary Office, London.

Sims, H. J. (1977). Cultivation and Fallowing Practices. In J. S. Russel and E. L. Greacen (eds.) *Soil Factors in Crop Production in a Semi-arid Environment.* The Australian Society of Soil Science and Queensland University Press, Brisbane, Australia. 244-261.

Sluggett, P. and Farouk-Sluggett, M. (1984). The Application of the 1858 Land Code in Greater Syria: some Preliminary Observations. In T. Khalidi (ed.) *Land Tenure and Social Transformation in the Middle East.* American University of Beirut, Beirut. 409-421.

Smilauer, P. (1992). *CANODRAW 3.0 User's Guide.* London.

Snobar, B. A. (1987). Impact of Mechanization of Wheat Production in Rainfed Areas of Jordan. *Rachis,* 6 (1), 35-40.

SPSS Inc. (1990). *SPSS/PC+ Base.* Chicago.

Stickley, S. T. and Abu-Shaikha, A. (1972). The Role of Land Tenure in Agricultural Development: the Bani-Hasan Area of Jordan. *Options Mediterranéennes,* 11, 80-83.

Stewart, J. I. (1988). Response Farming. In In Jaradat A. A. (ed.) *An Assessment of Research Needs and Priorities for Rainfed Agriculture.* The United States Agency for International Development, Jordan. 342-384.

Stewart, J. I. (1989a). Mediterranean-Type Climate, Wheat Production, and Response Farming. In C. E. Whitman, J. F. Parr, R. I. Papendick and R. E. Meyer (eds.) *Soil, Water, and Crop/Livestock Management Systems for Rainfed Agriculture in the Near East Region.* USDA/USAID/ICARDA, Washington. 5-19.

Stewart, J. I. (1989b). Response Farming for Improvement of Rainfed Crop Production in Jordan. In C. E. Whitman, J. F. Parr, R. I. Papendick and R. E. Meyer (eds.) *Soil, Water, and Crop/Livestock Management Systems for Rainfed Agriculture in the Near East Region.* USDA/USAID/ICARDA, Washington. 288-306.

Tabak, F. (1991). Agrarian Fluctuations and Modes of Labour Control in the Western Arc of the Fertile Crescent, c. 1700-1850. In Ç. Keyder and F. Tabak (eds.) *Landholding and Commercial Agriculture in the Middle East.* State University of New York Press, Albany. 135-154.

Taminian, L. (1990). 'Ain. In M. Mundy and R. S. Smith (eds.) *Part-Time Farming. Agricultural Development in the Zarqa River Basin, Jordan.* Institute of Archaeology and Anthropology, Yarmouk University, Irbid, Jordan. 13-59.

Tivy, J. (1990). *Agricultural Ecology.* Longman Scientific and Technical, UK.

Tomaselli, R. (1977). Degradation of the Mediterranean Maquis. In MAB Technical Notes 2: *Mediterranean Forests and Maquis: Ecology, Conservation and Management.* UNESCO, Paris. 33-72.

Townsend, C. C. (1974) *The Flora of Iraq: Leguminales.* Vol. 3. Ministry of Agriculture, Baghdad.

Townsend, C. C. and Guest, E. (1968) *The Flora of Iraq: Gramineae.* Vol. 9. Ministry of Agriculture, Baghdad.

Townsend, C.C. and Guest, E. (1980) *The Flora of Iraq: Bignoniaceae to Resedaceae.* Vol. 4 (2). Ministry of Agriculture, Baghdad.

Trabaud, L. and J. Lepart (1980). Diversity and Stability in Garrigue Ecosystems after Fire. *Vegetatio*, 43, 49-57.

Trabaud, L. (1981). Impact of Man and Fire. In F. di Castri, D.W. Goodall and R.L. Specht (eds.) *Mediterranean Type Shrublands.* Ecosystems of the World 11. Elsevier Scientific Publishing Co., Amsterdam. 523-537.

Tristram, H. B. (1866). *The Land of Israel: A Journal of Travels in Palestine.* Society for Promoting Christian Knowledge, London.

Tully, D. (1989). Rainfed Farming Systems of the Near East Region. In C. E. Whitman, J. F. Parr, R. I. Papendick and R. E. Meyer (eds.) *Soil, Water, and Crop/Livestock Management Systems for Rainfed Agriculture in the Near East Region.* USDA/USAID/ICARDA, Washington. 20-34.

Tully, D. R. (1990). Household Labour Issues in West Asia and North Africa. In D. Tully (ed.) Labour and Rainfed Agriculture in West Asia and North Africa. Kluwer (Academic Publishers for ICARDA), Dordrecht. 67-92.

Turkowski, L. (1969). Peasant Agriculture in Judean Hills. *Palestine Exploration Quarterly*, 101, 21-33 & 101-112.

Tutwiler, R. and Mazid. A. (1990). Adoption of Winter-Sown Chickpeas in Syria. Farm Resources Managment Program. ICARDA, Aleppo, Syria. 202-235.

Tüxen, R. (1950). Grundriss einer Systematik der nitrophilen Unkrautgesellschaften in der Eurosiberischen Region Europas. *Mitteilungen der Floristisch-Soziologischen Arbeitsgemeinschaft*, 2, 94-174.

Unger P. (1984). *Tillage Systems for Soil and Water Conservation.* FAO Soils Bulletin 54. FAO, Rome.

Uphof, J. C. Th. (1968). *Dictionary of Economic Plants.* Cramer, Lehre (2nd edition).

USDA (1975). *Soil Taxonomy.* Agricultural Handbook No. 436. USDA, Washington.

Veen, M. van der (1992). *Crop Husbandry Regimes. An Archaeobotanical Study of Farming in Northern England 1000 BC-AD 500.* Sheffield Archaeological Monographs 3. Department of Archaeology and Prehistory, Sheffield University, Sheffield.

Wåhlin, L. (1987). Diffusion and Acceptance of Modern Schooling in Rural Jordan. In R. I. Lawless (ed.) *The Middle Eastern Village: Changing Economic and Social Relations.* Croom Helm, Beckenham, Kent. 145-174.

Walkely, A. (1947). A Critical Examination of Methods for Determining Organic Carbon and Nitrogen in Soils. *Soil Science*, 63, 251-264.

Weuleresse, J. (1946). *Paysans de Syrie et du Proche-Orient.* Gallimard, Paris.

Whitelaw, T. M. (1991). The Ethnoarchaeology of Recent Rural Settlement and Land use in Northwest Keos. In J. F. Cherry, J. L. Davis and E. Mantzourani (eds.) *Landscape Archaeology as Long-Term History: Northern Keos in the Cycladic Islands from Earlierst Settlement until Modern Times.* Monumenta Archaeologica

16. Institute of Archaeology, University of California, Los Angeles. 403-454.

Woolf, E. R. (1966). *Peasants.* Prentice-Hall, Englewood Cliffs, New Jersey.

Williams, P. C., el-Haramein F. J. and Adleh, B. (1984). Burghul and its Preparation. *Rachis,* 3 (2), 28-30.

Williamson, T. (1989). Settlement, Hierarchy and Economy in Northwest Essex. In K. Branigan and D. Miles (eds.) *The Economies of Romano-British Villas.* J. R. Collis Publications, Sheffield. 73-82.

Wilson, C. T. (1906). *Peasant Life in the Holy Land.* Murray, London.

Zeist, W. van and S. Bottema (1982). Vegetational History of the Eastern Mediterranean and the Near East during the Last 20,000 Years. In J. L. Bintliff and W. van Zeist *Palaeoclimates, Palaeoenvironments and Human Communities in the Eastern Mediterranean Region in Later Prehistory.* 2 vols. BAR International Series 133, Oxford, 277-321.

Zohary, D. (1989). Domestication of the Southwest Asian Neolithic Crop Assemblage of Cereals, Pulses, and Flax: The Evidence from the Living Plants. In D. R. Harris and G. C. Hillman (eds.) *Foraging and Farming: The Evolution of Plant Exploitation.* One World Archaeology 13. Unwin Hyman, London. 359-373.

Zohary, M. (1940). The Vegetational Aspect of Palestine Soils. *Palestine Journal of Botany, Jerusalem,* 2, 200-246.

Zohary, M. (1949-50). The Segetal Plant Communities of Palestine. *Vegetatio,* 2, 387-411.

Zohary, M. (1960). The Maquis of *Quercus calliprinos* in Israel and Jordan. *Bulletin of the Research Council of Israel,* 9 (D), 51-74.

Zohary, M. (1962). *The Plant Life of Palestine (Israel and Jordan).* The Ronald Press Co., New York.

Zohary, M. and Fienbrun-Dothan, N. (1964-86). *Flora Palaestina.* 4 vols (Vol. 1-2 edited by M. Zohary; Vol. 3-4 edited by N. Feinbrun-Dothan). Israel Academy of Sciences and Humanities, Jerusalem.

Zohary, M. (1973). *Geobotanical Foundations of the Middle East.* 2 vols.. Gustav Fischer Verlag, Stuttgart.