# The maintenance of arable cropping in Canterbury

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## Abstract

Arable cropping systems practised in Canterbury are described and assessed on the basis of their use of alternative/sustainable technologies to maintain arable crop and grass/legume pasture yields. The alternative/sustainable quality of current arable cropping systems is not rated highly. A superior arable cropping system involving an eight-year-long rotation with alternate four-year-long phases of grass/legume pasture and successive arable crops of peas, wheat, white clover and barley is described in detail. It is recommended that further developmental research into alternative/sustainable technologies be initiated.

***Additional key words:*** *alternative agriculture, sustainable agriculture, crop rotation, soil fertility, soil structure, weeds, diseases and pests, grass/legume pasture.*

## Introduction

In recent years concerns for agriculture and the environment have prompted interest in the ideas of alternative and sustainable agriculture. The matter of sustainable agriculture and organic food production in New Zealand was considered about a year ago (Popay, 1990). However, few, if any, agronomists have publicly attempted an assessment, in terms of alternative and sustainable qualities, of any one of the several major systems which characterize New Zealand agriculture. This paper, therefore, undertakes an assessment of arable cropping as it is practised in Canterbury, relative to the concepts and objectives of alternative and sustainable agriculture and offers suggestions for a superior arable cropping system.

Sponsors of alternative agriculture hope to maintain crop yields, conserve soil, improve water quality and lower farm costs through reduced use of agricultural chemicals, greater use of legume/non legume rotations, wider use of improved crop and pasture cultivars and the development of integrated pest management and biological control (Committee on the Role of Alternative Farming Methods, 1989). Proponents for sustainable agriculture seek maintenance of long term productivity and prosperity in agriculture. Some consider sustainable agricultural systems have agronomic, economic, environmental, political and social dimensions (Stenholm and Waggoner, 1990). A local administrator has stated "sustainable management [of agriculture] requires that the environmental, social and economic needs of both current New Zealanders and future generations be explicitly considered" (Anon. 1991). Overall the objectives of alternative agriculturalists and those who promote sustainable agriculture appear similar and to differ only in their areas of emphasis. Alternative agriculturalists seem more concerned with the ways of achieving their objectives, and sustainable agriculturalists with economic, political and social issues.

For the purpose of this paper the objectives of alternative and sustainable agricultures are combined, and for convenience designated sustainable agriculture. Thus a sustainable arable cropping system is defined as one which, based on the best available technical information, maintains crop and pasture yields, and gives farmers reasonable rewards without causing permanent damage to or depletion of the arable cropping resource.

## Arable Cropping in Canterbury

Arable cropping on suitable soils of the Canterbury plains and downlands (Kear, Gibbs and Miller, 1967) generally involves forage crops, cash crops and grass/legume pastures. The areas of individual farms sown in arable crops or grass/legume pastures vary widely, and, with changes in the relative profitability of arable crop and livestock products, frequently. The forage crops, mainly turnips, kales and winter/spring greenfeeds, are fed *in situ* to livestock to supplement seasonal deficits in pasture growth. The cash crops, principally wheat, barley, peas and pasture seeds are harvested and their produce sold for use elsewhere. The grass/legume pastures are grazed by livestock, commonly sheep, and, frequently yield pasture seeds. Inputs of fertilizers, herbicides, fungicides and insecticides are made to arable crops but the rates and frequencies of their application are highly variable. Likewise, widely differing inputs of lime, fertilizers and insecticides are made to pastures but farmers commonly overlook the needs of pastures for phosphatic/sulphatic fertilizers. In those districts where water is available arable crops and grass/legume pastures are irrigated at intervals throughout the late spring and summer.

Usually Canterbury arable soils are continuously cropped for several years and afterwards spelled under grass/legume pasture for two or more years before further arable cropping is undertaken. Generally, both the numbers of arable crops successively cultivated, and the length of time arable soil is spelled tend to be more strongly influenced by short-term commercial considerations than by agronomic principles. The arable cropping systems practised in Canterbury are locally known as 'mixed farming', a not inappropriate term because arable cropping is characterized by the virtual absence of a common or standard system.

Yields of Canterbury arable crops and grass/legume pastures vary markedly, both among individual farms, and cropping years. Poor yields are attributed, in part, to unusual climatic conditions and other factors about which the farmer can do little, and in part, to other causes such as poor soil fertility, weeds, plant diseases and pests, many of which the farmer can counter. The measures taken to counter yield-limiting factors contribute to the sustainable quality or character of Canterbury arable cropping systems.

## Soil Fertility and Soil Structure

In Canterbury, arable cropping has long been associated with depletion of soil fertility, especially plant-available nitrogen, and deterioration of soil structure. Conversely it is generally considered grass/legume pastures improve both soil fertility and soil structure (Sears, 1951).

Field experiments on Canterbury arable soils have shown that repetitive arable cropping soon exhausts soil reserves of plant-available nitrogen and that application of fertilizer nitrogen is necessary to maintain forage yield in greenfeeds, grain yield in barley and both grain yield and bread-making quality in wheat (McLeod, 1974; Drewitt, 1978; Drewitt and Smart, 1981; Stephen, Saville and Lindley. 1989). Notwithstanding, pea yields appear little affected by either soil reserves of plant-available nitrogen or applications of fertilizer nitrogen (McLeod, 1987).

A recent survey of three arable soils in Canterbury showed repetitive arable cropping seriously depletes soil aggregate stability which after four years is likely to be so reduced that arable crop growth and yield are disadvantaged (Haynes, Swift and Stephen, 1991). The quality of aggregate stability is especially important to the pea crop as root rot infections tend to be more severe in compacted soils (Scott, 1987). The survey (Haynes, *et al.*, 1991) showed, also, that poor aggregate stability is improved when a depleted arable soil is spelled under grass/legume pasture for not less than four years.

Although the limiting effects of low concentrations of plant-available nitrogen in arable soils can be countered by application of fertilizer nitrogen such treatment has little positive effect on soil aggregate stability. The binding carbohydrates necessary for aggregate stability, accumulate only under grass/legume pastures. The different effects of repetitive arable cropping and grass/legume pastures on soil fertility and soil structure make it desirable that arable cropping systems include alternate phases, a grass/legume pasture phase, continued for not less than four years and an arable cropping phase which should not be prolonged for more than four years.

Generally on Canterbury arable soils yields of wheat, barley and pea crops are little improved by application of phosphatic, potassic and sulphatic fertilizers whereas grass/legume pasture yields respond well to these materials (McLeod, 1962; Grigg and Stephen, 1974; Stephen, 1980). Notwithstanding the generally poor response in wheat, barley and peas to PKS fertilizers it is usual practice among Canterbury arable cropping farmers to make 'insurance' applications to arable crops and to withhold applications from grass/legume pastures. The greater responses from grass/legume pastures to PS fertilizers suggest these materials could with advantage be diverted from most arable crops and applied more generously to grass/legume pastures.

## Weeds

Competitive and contaminant weeds are a problem on Canterbury arable cropping farms. In the absence of an effective systematic programme of fallowing and herbicide applications repetitive arable cropping leads to the establishment of dense weed populations. Some weeds possibly have little effect on the growth and yields of arable crops but others notably wild oats (*Avena fatua* and *Avena persica*) (Butler, 1980), fathen (*Chenopodium album*), Californian thistle (*Cirsium avense*) and willow weed (*Polygonum persicaria*) seriously compete with arable crops and their seeds contaminate arable cash crop produce.

Although the rhizomatous weeds yarrow (*Achillea millefolium*) and twitch (*Agropyron repens*) are readily controlled by a cultivated fallow the general overall superiority of applications of selected herbicides as a means of weed control is such that control of most arable weeds by herbicides is currently the only practical option available to the arable cropping farmer. However should herbicide resistance in arable crop and pasture weeds develop more widely than is the case at present (Rahman, 1982; Rahman and Patterson 1987; Bourdot and Hurrell, 1988, Harrington, 1989; and Bourdot, Harrington and Popay, 1989) it will become necessary to control weeds by cultivation and weed/crop interaction techniques (Popay, Bourdot and Rahman 1989).

In the meanwhile it appears Canterbury arable cropping farmers will continue to rely on strategic applications of selected herbicides as the means of suppressing weed growth in arable crops and grass/legume pastures.

## Arable Crop and Pasture Diseases

A wide range of disease conditions caused by pathogenic fungi, some bacteria and viruses have potential to cause yield losses of major economic significance in most arable crops cultivated in Canterbury. Wheat and barley, for example, host respectively 16 and 17 pathogens (Anon. 1991). Generally each pathogen has potential to infect only one host but some such as Take-all (*Gaeumannomyces graminis* var *tritici*) and the foot rots (*Fusarium* spp.) have wider host ranges.

Some pathogens are spread by the sowing of infected seeds and others by air-borne spores but many are passed to succeeding crops from preceding crops by infected crop residues and volunteer crop plants. Fortunately the limited host specificity of most pathogens coupled with their spread by infected crop residues and volunteer crop plants offer substantial opportunity for their containment by field hygiene practices. These practices ensure that arable crops susceptible to the same pathogens are not successively cultivated and that infected crop residues are destroyed soon after crop harvest by firing and deep ploughing. However, on many arable cropping farms in Canterbury crop residues are not destroyed promptly but are used as livestock forages and tend to be left long after their limited forage potential has been exhausted. Such practices provide ample opportunity for disease transmission.

Unfortunately infection of clean crops by air-borne spores as in the case of stripe rust of wheat (*Puccinia striiformis*) cannot be prevented by the field hygiene practices of the individual farmer and it is often necessary to make strategic applications of a selected fungicide. Two strategies are employed in the use of fungicides. Insurance applications are made prior to the detection of disease symptoms to prevent infection, and control applications are made after pathogen infection. Both strategies have advantages and disadvantages but use of insurance applications may lead to unnecessary treatment.

Plant breeders and other manipulators of arable crop germplasm have induced resistance to specific pathogens in some arable crops. Disease control achieved in this way has often been rendered ineffective by pathogen mutation. Grass/legume pastures are susceptible to a range of pathogens but control measures are rarely employed.

It is anticipated Canterbury arable cropping farmers will continue to control crop diseases by the use of purposely selected crop cultivars, field hygiene practices and strategic applications of selected fungicides, etc.

## Pests of Arable Crops and Pastures

Several insect pests have regularly and severely reduced yields of Canterbury arable crops and grass/legume pastures. Generally control of insect pests has been achieved by applications of insecticides but the breeding of pest resistance into arable crops and use of alternative technologies have been successful.

In the case of wheat, infestation by the cereal aphid, *Rhopalosiphum padi*, is significantly reduced by delay in seeding from mid April to mid May so that wheat seedlings emerge after the final autumn flight of the aphid (Close, 1969). Later infestations of wheat and barley by the rose-grain aphid, *Metropolophium dirhodum*, are biologically controlled by the parasitoid (*Aphidius rhopalosiphi*) (Stufkens and Farrell, 1987).

Damage to grass/legume pastures caused by grass grub (*Costelytra zealandica*) and porina caterpillars (*Wiseana* spp.) has been limited by applications of selected insecticides. In the case of grass grub, infestations attain maximum densities in three to four-year-old pastures (Jackson *et al.*., 1989). It has been suggested that prior to the point of maximum infestation pastures should be cultivated and the area cropped. However more recent developments show grass grub infestations of grass/legume pastures can be biologically controlled by inundative application of the bacterium

*Serratia entomophila* (Jackson, 1990; Jackson *et al.*, 1991).

Recent identification of the *Acremonium lolii* endophyte strain which does not induce ryegrass staggers points to a biological means of controlling Argentine stem weevil (*Listronotus bonariensis*) in perennial ryegrass pastures (Fletcher *et al.*, 1990).

Notwithstanding developments of the kind mentioned above strategic applications of selected insecticides are likely to remain important means of controlling many arable crop and grass/legume pasture pests.

## A Sustainable Quality Rating

One objective of this paper is the assessment or rating of the sustainable quality of the arable cropping systems practised in Canterbury. This exercise is made difficult by the lack of a recognized standard and objective method of assessment. Nonetheless the above review of Canterbury arable cropping systems highlights some practices which contribute positively to the aims of alternative and sustainable agriculturalists and others which either disregard sound agronomic principles or involve the use of agricultural chemicals manufactured from steadily declining resources, and thereby detract from the sustainable quality of present arable cropping systems. Consideration of the sustainable quality of inputs and practices involved in Canterbury arable cropping systems suggest that fewer than thirty percent of all current inputs and practices can be rated sustainable.

## A Superior Arable Cropping System

The second aim of this paper is to offer suggestions for an improved arable cropping system, one that makes wider use of alternative technologies and thereby confers greater sustainability on arable cropping in Canterbury.

The superior arable cropping system involves grass/legume pastures, wheat, barley, peas and white clover combined in an eight year rotation with grass/legume pastures maintained for four years and followed in turn by peas, wheat, white clover and barley. The more important practices differing from present management systems are:

*1.* the strictly enforced alternation, in four-year long phases, of grass/legume pastures and arable cash crops.

*2.* the use of grass/legume pasture as the means of rebuilding soil fertility and soil aggregate stability previously depleted by arable cash cropping.

*3.* the exploitation of soil fertility and aggregate stability built up under pasture, by arable cash crops.

*4.* the diversion of 'insurance applications' of PS fertilizers from pea, wheat and barley crops to grass/legume pastures.

*5.* the application of *Serratia entomophila* to two-year-old grass/legume pastures in order to control grass grub infestation.

*6.* the hard close grazing of grass/legume pastures in late spring and early summer in order to minimize porina caterpillar establishment.

*7.* the use of grass/legume pastures and pea straw as livestock forages.

*8.* the sowing of arable crops in sequences which separate crops susceptible to the same pathogens.

*9.* the sowing of peas, without fertilizers, after fourth year pasture, in order to take advantage of improved soil structure and thereby minimize damage by pea root rots.

*10.* the mid-May seeding of wheat, without fertilizers, after peas; to avoid the late flights of the cereal aphid and soil-borne wheat pathogens and to take advantage of high soil concentrations of plant-available nitrogen.

*11.* the under-sowing of the wheat crop with white clover in order to build up soil nitrogen concentrations and minimize disease transmission from wheat to barley.

*12.* the winter seeding of barley, without fertilizers, after white clover so as to take advantage of moderately high soil concentrations of plant-available nitrogen and minimize disease transmission from wheat to barley, and to facilitate late summer sowing of new pasture.

*13.* the prompt removal of arable cash crop straw and the deep burial by ploughing of residues and volunteer plants to minimize spread of crop pathogens.

In addition to the amended practices listed above the superior arable cropping system will necessarily continue to rely on established practices such as the strategic use of fertilizer nitrogen, herbicides, fungicides and insecticides. The sustainable quality of all inputs and practices involved in the superior arable cropping system suggests that some fifty percent can be rated alternative and sustainable.

## Conclusions

In Canterbury, arable cropping systems contribute usefully to the economy and social welfare of the local community. It is not unreasonable therefore that arable cropping practices and efficiencies be scrutinized with the view to maintaining both arable crop yields and arable cropping resources. This brief review of Canterbury arable cropping systems and the examination of their sustainable qualities indicate that although some alternative practices are widely established within present arable cropping systems there remains a substantial reliance on practices which are neither alternative nor sustainable. The present sustainable state of arable cropping in Canterbury is modest but certainly not poorer than that of most farming systems in New Zealand, and moreover probably superior to that of some pastoral livestock systems.

The proposed arable cropping system, based on an eight-year rotation of equal alternate phases of grass/legume pasture and arable cash crops, and offered as a superior alternative to present systems, involves a higher proportion of grass/legume pasture for a longer period than is usual at present. Its general acceptance therefore will depend on relative cash returns available from arable cash crops and livestock products. Its general success will be determined by the individual farmer's capacity to cope efficiently with both arable cropping and livestock.

Further improvement to the sustainable quality of Canterbury arable cropping systems requires wider use of alternative practices. Before this can be done additional developmental research in these areas is required. Indeed it would be prudent and substantially rewarding to redirect most current agronomic research to that end.

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