PASTURE CONDITION AND SOIL DESICCATION AS INFLUENCES ON TUNNEL-RELATED EROSION

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Tunnel gully erosion at Wither Hills, Blenheim in the 1950's.

ABSTRACT

Soil conservation control measures have been developed to ameliorate the effects of tunnel-related erosion on agriculture in areas of New Zealand, usually areas with seasonally dry loessial soils. These control measures have included: mechanical destruction of both tunnels and related gullies, establishment of improved pasture, and maintenance of that pasture by lenient grazing. They were designed with the assumption that tunnels had formed as a result of concentrated water penetration into the subsoil via desiccation-induced shrinkage cracks.

Criticism of previous research into the various aspects of tunnel-related erosion was undertaken and enabled the identification of some limitations, contradictions, and wrongly placed emphasis, in the accepted model of tunnel formation in loessial soils in New Zealand.

An experiment was designed to measure the effects of grazing intensity upon soil moisture levels. This experiment resulted in the rejection of the accepted mechanism by which leniently grazed pasture was thought to reduce soil drying and subsequent cracking, as soil drying actually increased with longer pasture. It could not be disproved that the supposed effects of lenient grazing were actually due to the accompanying mechanical treatment or possible climatic changes. However it was shown to be highly likely that the effects of lenient grazing were due to the promotion of the pasture's root growth. Enhanced root growth could restrict both crack development and tunnel initiation, and encourage intact tunnel roof subsidence rather than complete roof destruction - a precursor to gullying. Development of strong root systems is particularly encouraged by lenient grazing in late autumn and early spring. It is recommended that grazing by cattle instead of sheep continue in the areas with seasonally dry loessial soils subject to tunnel-related

erosion. Particular care should be taken in late autumn and early spring to ensure that pasture is not overgrazed. This recommendation is qualified by economic considerations which may dictate that cattle grazing is untenable.

Further research into the effects of grazing on the development of root systems of pasture species is also recommended. This research would have implications for the control of a number of erosion types throughout New Zealand but has unfortunately been largely ignored in the past.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Page

CHAPTER 1 INTRODUCTION

1i General background

Subsurface erosion (piping, tunnel-gully etc) has been recognised as a significant erosion problem in New Zealand since at least the late 1930's particularly in areas with loessial soils. Early descriptions by Taylor (1938), Cumberland (1944) and Gibbs (1945) were among work which stimulated state intervention via the then Public Works Department in the field of soil conservation. The most spectacular subsurface erosion in New Zealand occurred on the Wither Hills near Blenheim, where it was referred to as tunnel-gully erosion (Gibbs 1945). Historical records and the pedological surveys of Laffan (1973) both indicated that this erosion was at most minimal before the clearance of scrub and tussock in the period 1860-1900. This indicates that it was man-induced or "accelerated" erosion. Accelerated erosion is that which occurs at rates above the natural or geological erosion rates.

Prior to European settlement the climate, soils, vegetation and topography had developed into a state of dynamic equilibrium. The Polynesian inhabitation of Marlborough was accompanied by widespread burning of the indigenous vegetation and possibly resulted in an increase in erosion though not of the same magnitude as that which followed European settlement (Laffan, 1973). The major difference between Polynesian and European settlement was the influx of grazing animals and the development of agriculture associated with the latter. The effect of the animals, principally sheep and rabbits, when accompanied by burning, was a widespread and continued reduction in the original vegetative cover. Subsurface erosion can be seen as an attempt by the pedological, hydrological and topographical elements to regain balance with the changed vegetative and faunal influences. On the Wither Hills, control of these biological influences before 1940 resulted in the situation whereby the soil could not cope with the rainfall. The

soil was being lost downslope in tunnel-gullies and as surface wash. Hence the related problems of flooding and soil erosion.

This was the situation when the Public Works Department established the Wither Hills Soil Conservation Reserve in 1944. The Reserve was used as an example of the productive benefit that could be obtained when appropriate management was applied to susceptible areas. Principal soil conservation measures applied were:

- smoothing affected slopes (by bulldozing);
- establishment of improved pasture (deeper rooting and more resistant to drought than former pasture);
- a change to grazing by cattle instead of sheep.

It was thought that analysis of the effects associated with these control techniques may not only provide insights into improving erosion control but also into those processes which operate to initiate subsurface erosion.

Previous research has concentrated on those properties which have been believed to make a soil susceptible to tunnelling. Examples are high levels of potential shrinkage, dispersibility and slaking (Miller 1971, Laffan 1973, Wilms 1979, and others). This line of work ignored the fact that these soils probably had these same properties before severe erosion commenced following European settlement. It is apparent that factors other than the soil properties previously investigated, were responsible for the widespread initiation of tunnel-gully erosion in the period 1860-1940. It is probable that those same factors need to be controlled today if tunnel-gullying is not to redevelop.

It is suggested that the alteration and destruction of the original vegetation was the single event primarily responsible for the initiation of tunnel-gully erosion following European settlement. Conservation works have

generally comprised attempts to reverse these effects by re-establishing a 'good' vegetative cover. This does not preclude the possibility that some tunnelling occurred before European settlement. Some large tunnels may well have existed prior to 1860. The reduction in vegetative cover - reduction in root mass/root strength - may well have been sufficient to cause these tunnels to collapse and form gullies. The effects on soil stability associated with the reduction in vegetative cover will be described in a later chapter.

Section ii of this chapter describes the development of soil conservation in New Zealand. This provides a background against which the current aims and ideals of soil conservation (research) can be placed and the value of such clearly seen. In later chapters the processes of subsurface erosion will be examined in some detail, important soil and climatological factors described and soil conservation measures (and their effects) discussed.

There seems little doubt that the conservation works used to control tunnel-gully erosion have been beneficial. (Marlborough Catchment Board, 1981). However it is still unclear as to whether these are the best of the possible options, whether they will continue to be successful, or why they have been successful.

It has been thought that the main effect of removal of vegetation is an increased development of soil shrinkage cracks. However after reviewing and interpreting the literature this effect is seen to be but one of several, and possibly not the most significant.

It was initially expected that the extensive fieldwork planned would elucidate the relationships between levels of grazing, soil moisture levels (desiccation) and the development of shrinkage cracking. The degree to which

this could happen was restricted by the wetter than normal summer of 1985-86 but considerable useful information relevant to such (postulated) relationships was gained nevertheless.

Other work involved measuring the relationships between pasture condition and root development. The question of whether the erosion could have been the result of special climatic conditions was also investigated. In an effort to achieve a more cohesive study, additional information was obtained by an extensive search of the literature. This revealed a number of contradictions and omissions in previous research into subsurface erosion. It is hoped that these have been elucidated and our understanding of the topic improved by the preparation of this thesis.

1ii An appraisal of soil conservation

Rose (1985) characterised the operation of soil conservation into three (not necessarily sequential) phases. These were:

i) identification and quantification of processes;
ii) development of soil conservation practices;
iii) evaluation of options into overall policies of land use.

In New Zealand these three phases are apparent, though not complete, and have been subject to continual re-evaluation since the first state intervention into soil conservation in the late 1930s. This intervention was stimulated by the two disastrous East Coast floods of 1938, particularly the 'Anzac storm' which afflicted the Tangoio area north of Napier. This storm clearly brought to public attention the problems - such as soil loss, flooding, lowered water quality, lowered soil fertility and increased slope instability - caused by unsuitable land use practices (McCaskill, 1973). The next few years saw increasing awareness of the types and magnitude of the soil erosion

problem facing New Zealand with publications by Taylor (1938), a Committee of Inquiry headed by Taylor (1939), Cumberland (1944), Gibbs and Raeside (1945), Gibbs (1945), Campbell (1945 a, b), and Grange and Gibbs (1946).

Hudson (1981) observed that major soil conservation programmes have only occurred where they have been heavily subsidised by the state. He viewed soil conservation as an issue extending over the next 50 or 100 years given the probable development of cheaper synthetic food sources. This time scale was contrasted with that of those used by political leaders, acting as resource managers, whose outlook was thought to seldom extend beyond the next election, and of farmers who do not expect to pay now for preserving the land for posterity unless immediate economic benefits are also gained. Hudson concluded that soil conservation is in the greater long term interest of the state or community rather than the government of the day or any individual. The New Zealand experience reflects this description.

The Soil Conservation and Rivers Control Act was passed by Parliament in 1941. This Act created the Soil Conservation and Rivers Control Council (SCRCC) whose tasks included:

- the carrying out of surveys and investigations to ascertain the nature and extent of soil erosion in New Zealand;
- the carrying-out of experiments and demonstrations in soil conservation and reclamation;
- the investigation and design of preventative and remedial measures in respect of soil erosion (McCaskill, 1973).

The SCRCC administered the formation of Catchment Boards in those areas where soil erosion and flooding were serious problems. It was through these local bodies and the Public Works Department that the policies of the SCRCC were implemented. The functions of the SCRCC (and the Water

Resources Council) are now discharged by the National Water and Soil Conservation Authority (NWASCA), while the Public Works Department has evolved into the Ministry of Works and Development.

Since 1941 the available soil conservation technologies have changed resulting in better definition of erosion processes and costs and the development of more effective control techniques. Over these years the ethics and philosophies of land use have altered in several respects resulting in changing policies and practices which in turn affect the direction of erosion processes research.

NWASCA has statutory functions which include control of erosion and the wise management of (water and) soil resources (WASCO 41, 1984). NWASCA is serviced by the Water and Soil Directorate of the Ministry of Works and Development, including the three water and soil science centres. The work described in this thesis was carried out as part of the research programme of the Erosion Processes Group of the Soil Conservation Centre at Aokautere. According to Rose's classification (processes, practices and policies - see above) this study would form part of the link up between processes and practices from which appropriate land use policies can be formulated. NWASCA, MWD (Head Office Water and Soil Directorate), and Catchment Authorities are concerned dominantly with establishing policies and encouraging (by subsidy) practices. A principal function of the science centres, and a goal of this study is to strengthen the link between processes and practices.

Soil conservation studies have tended toward the pragmatic. That such an "if it works, do it" approach has been successful can be seen by the amelioration of many soil conservation problems over the last forty years. This approach came from the need to get results quickly if the serious erosion problems recognised were not to get worse.

This pragmatic approach also encouraged the non-specialist. The 1939 Report of the Committee of Inquiry recommended the development of a soil conservation programme involving the "active collaboration and co-operation of foresters, agrostologists[1], botanists, agriculturalists, engineers and soil technologists." Looking back it is possible to say that all of these fields of study plus many more have been involved in the development of soil conservation practices. Nevertheless for the formulation of practices and policies, from individual to national problems, decisions have been made that cut across such academic boundaries, hence the development of a generalist school of thought.

Soil conservation studies are not simply erosion studies in which a process oriented positivist approach would suffice. They are also land management studies which require adherence to a particular set of values or ethics regarding land use. Rose (1985) recognised this philosophical issue. Processes can be identified and quantified via scientific investigation, whereas selecting and designing practices requires "recognition of the priority order of social goals of the landholder" and the overall policy evaluation "depends upon consent to some philosophy or ethic or series of ethics".

For example the economic benefit consequent upon the implementation of conservation works is frequently used as justification although this depends on the land use: social benefits such as security, the ability to maintain a lifestyle, environmental conservation (flora and fauna as well as soils) and aesthetic enhancement, cannot be quantified but still need to be acknowledged.

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1 *Agrostology - the study of grasses*

The recognition of reasons why actions are taken may well be as important as what is done or how it is done. Soil conservation is neither science nor social science but the two combined into an integrated geographic discipline.

In this study an objective quantitative approach has been adopted for the investigation of those processes involved in the initiation and control of tunnel erosion. In considering the relationship of these findings to practices the assumption has been made that continued pastoral use of the land is desired. Consideration of changing this land use 'prejudice' is beyond the scope of this study.