CLUTHA VALLEY SOILS AND WATER RESOURCES DEVELOPMENT

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INTRODUCTION

There are two main problems facing us today – population growth and agricultural production. The facts of population growth are well known and our response to this challenge is growing. The problem of agricultural production is undoubtedly simpler than population growth, but is still one of immense difficulty. It is one in which all agricultural people are inextricably involved (Miller, 1970).

In New Zealand, the National Development Council's Agricultural Committee has this to say: "The attainment of the projections for agriculture and horticulture will depend on the effective use of *all agricultural land*". They then go on: "This is especially pertinent where valuable horticultural land is being threatened by urban expansion" (NDC, 1969a).

It should be noted here that urban expansion with its concomitant commerce and industry, all heavy users of electrical energy, not only absorbs land *per se* but also indirectly takes agricultural land by the increasing number of dams flooding more and more valleys.

"Consideration should be given to the establishment of suitable and acceptable criteria upon which any decision to change productive land use should be based." The Agricultural Committee presumed the Physical Environment Committee would study, as it was supposed to, the present and potential availability of land for competing productive, residential and recreational purposes (NDC, 1969b).

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At this point we may ask a question: Will society gain more from a Clutha River Project for power or a Cromwell High Terrace Project for irrigation? Water cannot be isolated from applications of other resources that are technical complements. Water is rapidly becoming a scarce resource giving rise to economic decisions in its use, but equally important are decisions relative to the use of labour, capital and soil – also scarce resources (Timmons and Kirkham, 1972). The attainment of many environmental as well as economic objectives will depend on putting land resources to the best combination of uses. It is essential, therefore, that a thorough knowledge of land resources and land use is available (NDC, 1969a).

In considering the best use to which society can put a given water or soil resource, thought must be given to tangible (usually economic) and intangible (usually cultural) benefits of these alternative uses. At any rate, in planning for the enhancement of soil and water resources planners must not ignore the other users of these commodities. Any excess for agriculture or power must be available for other users in a complementary fashion (Wadleigh, 1969).

The key to any form of land use involving soil is the soil map, and this is a great strength and working tool for an integrated, multi-discipline study (Leamy, 1971).

THE SOILS

Four main soil groups can be recognized, each being given a name characteristic of the subsoil colour (Leamy, 1967).

Brown-grey earths (BGE) lie in the semi-arid climatic zone where rainfalls average 300 to 450 mm annually. They are moisture deficient for at least nine months of the year and are the soils of the stone-fruit districts, occurring from Bannockburn to the Lindis River in the Upper Clutha Valley, through the Cromwell Gorge, and from Alexandra to Omakau, with a small patch near Roxburgh Dam. These soils are also represented in the Ida Valley and in the Maniototo.

The yellow-grey earths (YGE) occupy the subhumid zone which has a rainfall from 450 to 650 mm annually. Soils are moisture deficient for six months of the year and are more suited to pip-fruit growing. They cover those parts of Central Otago not covered by the brown-grey earths and are the main soils from Roxburgh to Millers Flat, from the Lindis River to Hawea Flat, and from Waitiri to Arrowtown.

The transitional yellow-grey/yellow-brown earths (YGE/YBE) occupy the subhumid-to-humid climatic zone around the fringes of the lakes near their outlets, and in parts of the Cardrona and Arrow basin. Rainfall is from 650 to 900 mm and moisture is deficient for three months of the year.

The yellow-brown earths (YBE) are confined to the more northern fringes of the lakes and to regions with rainfalls above 900 mm. They are not used for fruit growing – save at Beaumont – but are important pastorally and as the catchments of the streams and rivers used for irrigation and power. Moisture is not usually deficient.

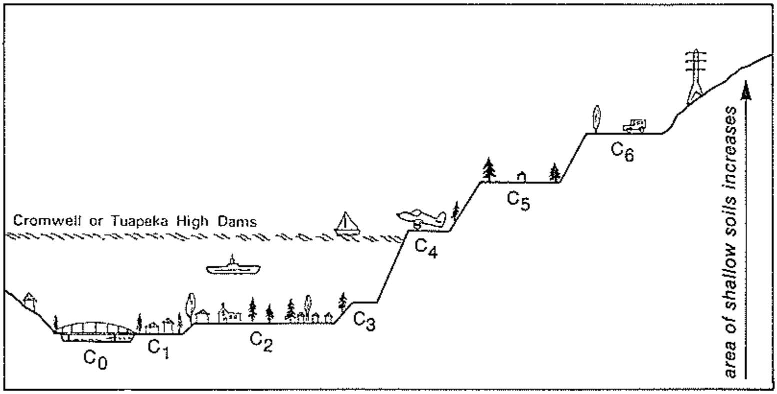

FIG. 1 — Terrace surfaces – Clutha Valley utilization shown by cultural features.

Within this main soil-group pattern there exists a complex of various textured soils all of which lie on a landscape comprising terraces, fans, scarps, and downs. The terrace pattern is well developed along the Clutha River, and it is fairly easy to recognize seven main terrace levels which can be called C_0 to C_6, from youngest to oldest; the oldest is usually the highest terrace and the youngest the river bed. This is shown diagrammatically in Fig. 1. Also included in Fig. 1 are the cultural features, which are shown approximately proportional to their order of occurrence. The treads of the terraces are similarly proportional to their area. The height of the old high dam proposals (Henderson, 1971) is outlined also, to give a visual impression of the rather catastrophic effect they would have on the cultural landscape.

For convenience, surfaces C_0 and C_1 are called low terraces, C_2 and C_3 intermediate terraces, and C_4, C_5 and C_6 are high terraces.

THE CLIMATE

In Central Otago, and along the Clutha River in particular, there is a region where the rainfall is as low as 325 mm annually. The climate is continental in character, with hot summers and cold winters. Over most of the region sunshine hours average about 2000 a year, with a slight decrease from Island Block to Tuapeka Mouth. There are about 100 raindays a year, and 20 percent of the rainfall falls during the winter months of June, July and August, giving a dry, cold, winter period.

Frosts can occur on any night of the year, so a large daily range of temperature is possible; a 17 deg C change between day and night temperature is not uncommon and a 30 deg C drop will occur at least once every summer. Cromwell, with a mean daily maximum temperature of 24° C in January, is the hot spot of Central Otago with the highest summer temperatures. Alexandra is a close second.

When considering the semi-arid and subhumid zones as a whole it can be seen that although day temperatures are high, night temperatures are frequently low, and this gives somewhat lower average temperatures than are desirable for certain crops to mature rapidly on a commercial scale – for example, sweet corn (maize). soyabeans and rice.

Where rainfalls are over 650 mm annually the soils formed occur widely over the South Island, but those under 650 mm are almost entirely restricted to Central Otago. This semi-arid climatic zone is unique and does not occur elsewhere in New Zealand. Even more unusual is the warm part of this zone which only occurs from Cromwell to Alexandra, and for this reason alone every attempt should be made to preserve the soils within the Cromwell and Cromwell Gorge areas as far down as Clyde.

AGRICULTURAL PRODUCTIVITY OF THE SOILS

The natural fertility of the soils, or their ability to produce crops without the aid of fertilizers, decreases as the rainfall increases. Roughly, this means that in their natural state brown-grey earth soils are more fertile than yellow-grey earths, and so on; similarly, in going up the terraces from youngest to oldest the soils get less fertile. In general, the higher the rainfall or terrace height – and this also applies to the fans – the less fertile the soil in its natural state.

This lack of fertility can be overcome by the use of artificial fertilizers, and for all practical purposes all soils can be brought to the same level of fertility. However, the soil productivity or the

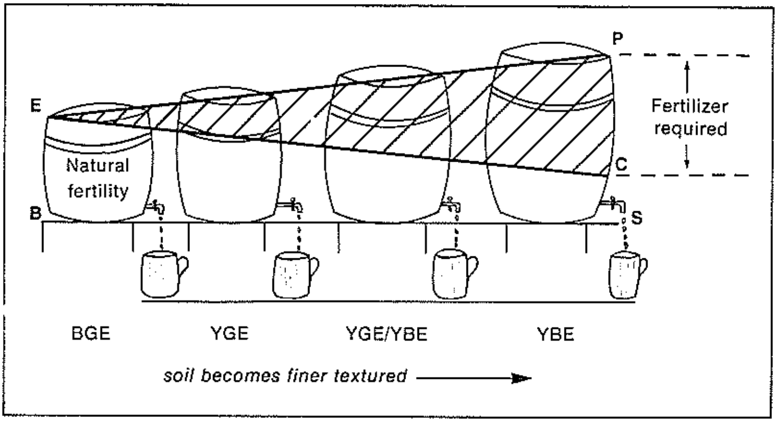

FIG. 2 — Fertility and productivity of soil groups. Height of line CE above BS gives order of natural fertility; height of line EP above CE gives order of fertilizer required; height of line EP above BS give order of productivity with fertilizer.

ability of the soil to give sustained high crop yields is closely related to its texture, depth, and amount of organic matter present. Generally, the finer the texture the higher the productivity. No matter what soil group or climatic zone is considered, the greater area of finer textured soils is on the low and intermediate terraces; the best soils are therefore on the C_1 and C_2 surfaces. The soils usually become shallower and stonier on the higher terraces and therefore of lower productivity. This is illustrated diagramatically in Fig. 2.

The productivity of the low and intermediate surfaces was highlighted in a study of 151 orchards in the Alexandra district (McCraw, 1964). Here it was shown that orchard productivity was directly related to soil depth and texture. Average and above-average orchards were on the deeper finer soils of the C_1 terrace and C_2 fan. Coarse-textured soils of the intermediate terrace were not nearly as productive. Because of high water tables and the danger of flooding there were few orchards on the C_0 or riverbed surface.

A similar effect is also shown in Table 1 for lucerne, where the finer-textured soils are higher producing than the coarse ones. The effect in the case of the dryland lucerne is of course due to differences in available moisture between deep fine-textured soils and shallow or coarse-textured soils and between stony and non-stony soils. On the irrigated lucerne the difference is solely due to texture.

If dryland or irrigated farming is forced off the lower more fertile terraces on to the shallow stony higher terraces where it is uneconomic to irrigate, there will be a decrease in pasture produc-

TABLE 1 — Effect of soil texture on lucerne production.

Annual rainfall (mm)	*Texture*	*Dry matter yield (kg/ha)*	
		Dryland	*Irrigated*
400	Stony very shallow sandy loam	300*	–
400	Sandy loam	2 200*	8 900*
400	Fine sandy loam	3 900*	13 700*
500	Sandy loam	4 000†	–
500	Fine sandy loam	4 500‡	–

* 3 years. †10 years. ‡4 years.

tion because of lower available moisture and so an increase in the number of drought days. An empirical relation given in Fig. 3 and based on 10 years' observations from 1961 to 1971 shows how ryegrass/white-clover pasture production declines as the number of drought days increases (drought days here being the number of days in which the soil is below wilting point).

So far no consideration has been given to the high-country and mountain soils and their associated tussock grasslands. The potential for fescue and snow-tussock grassland development along the Clutha is a real national asset and should be taken into account when the profitability of hydro-electric schemes is being assessed. It must be remembered that if the potential of fescue-tussock grasslands on the mountain ranges is to be realized, it is generally essential to produce winter feed on the flat terrace country – a percentage of which could be flooded when hydro-electric development takes place in this catchment.

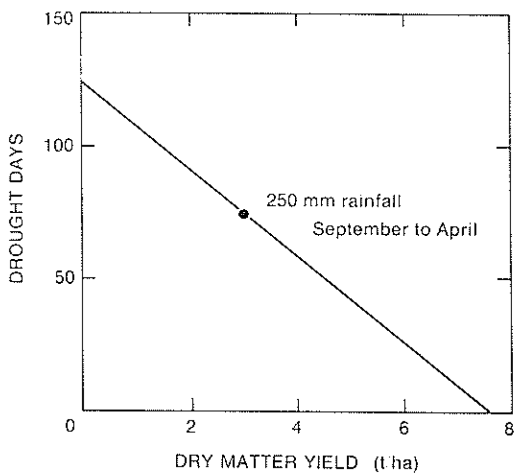

FIG. 3 — Pasture production versus drought days, 1961–62 to 1970–71.

Recent research work has shown that if the arable areas of the fescue and snow-tussock grassland were improved, then substantial amounts of dry matter could be produced even up as high as 1100 metres altitude. The decline in pasture production over the Otago Plateau for a ryegrass/cocksfoot/white-clover pasture as altitude increases is shown in Fig. 4. Since no data are available above 1100 metres, the zero-production altitude is a rather tenuous extrapolation.

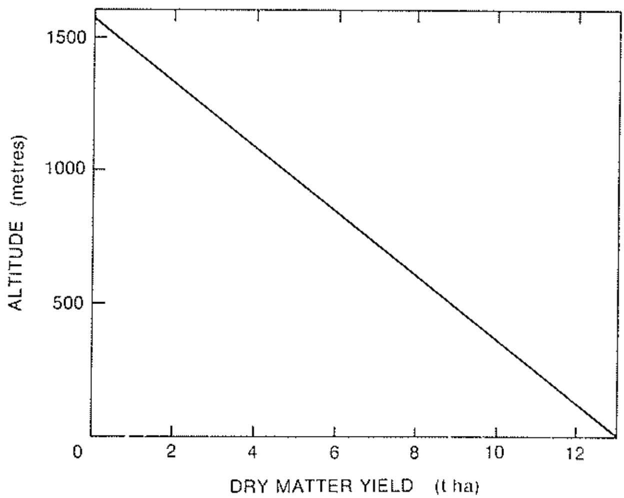

FIG. 4 — Pasture production versus altitude.

Table 1 and Fig. 3 show fairly clearly the decline in pasture production that can be expected if pastoral farming has to move on to stony or coarse-textured shallow soils, whilst Fig. 4 shows the decline in production that occurs if farming operations have to move to higher altitudes because of lack of lower country.

It is apparent then that any power-development scheme should as far as possible preserve the finer-textured soils of the C_1 and C_2 terrace and fan surfaces. This applies whether or not the soils are used at present. Soil is an international commodity, not just a New Zealand one, and scarce at that. At present there is no foreseeable complement or substitute for soil as there is in the case of electric power, so the better soils must be preserved.

Where agricultural productivity in general is concerned it is possible to group all soils (BGE to YBE) into six classes (Leamy, 1967) and rate the soils on a productivity and versatility basis. This rating was done in the Clutha River Survey, and an indication of

TABLE 2 — Production data for various soil productivity ratings.

	Class				
	I	*II*	*III*	*IV*	*V–VI*
Pasture —					
Dry matter (t/ha) :	13–18	11–15	9–11	7–9	3–6
Ewes per ha :	30–40	25–35	20–25	15–20	5–12
Wheat (t/ha) :	6.7	6.0	5.4	4.0	–
Stone fruit (t/ha) :	3.1	–	–	–	–
Pip fruit (t/ha) :	4.5	–	–	–	–
Berry fruit —					
Strawberries (t/ha) :	10–12	–	–	–	–
Boysenberries (t/ha) :	3	–	–	–	–
Raspberries (t/ha) :	3	–	–	–	–

the agricultural potential under irrigation was derived as shown in Table 2. The dry-matter production figures are those readily attainable and are about average figures for all districts (Radcliffe, 1974; Radcliffe and Cossens, 1974). Here again it must be emphasized that production is limited by the large daily temperature range and the frequency of frost at night. Class-I soils in the Lower Clutha might perform 10–15 percent better than in the Upper Clutha because of fewer frosts.

IRRIGATION

Table 2 considers the soil potential under irrigation. As a rough guide, irrigation increases pasture production three times in the BGE zone and two times in the YGE zone. The yellow-brown earth zone has a rainfall above 900 mm, and generally it is considered unnecessary to irrigate where the rainfall is 900 mm or more (Raeside, 1971). However, this is an arbitrary limit. The other point worth noting is that 70 percent of the dryland production on the BGE zone is produced in the spring so the effective carrying capacity is reduced, as the production is not evenly distributed during the growing season (Radcliffe and Cossens, 1974).

TABLE 3 — Areas of districts and their irrigable soils.

	Area of district (ha)	*Area of irrigable soils (ha)*
Arrow Basin–Gibbston	14 000	5 100
Upper Clutha	60 000	34 200
Cromwell Gorge	800	700
Alexandra–Earnscleugh	8 000	4 900
Roxburgh–Island Rock	6 000	3 200
Beaumont–Tuapeka Mouth	900	0
Total:	89 700	48 100

In considering the use of water for power or agriculture it is as well to look at the total area of land of the several terraces on the valley floor between Tuapeka Mouth and the lakes and consider what land could be readily irrigated. Approximate areas extracted from the 1:253 440 (4 miles to 1 inch) soil maps for readily irrigable soils are given in Table 3. This would indicate about 54 percent of the area as being irrigable, which is generous for Central Otago topography. The other notable feature which shows up in Table 3 is the small amount of land (89 700 ha) available along the valley floor.

Allowing water at 200 m^3/h per 100 hectares of land irrigated – which for some areas is liberal – then the total irrigation and domestic requirement would be of the order of 130 000 m^3/h, which is about 10 percent of the flow at Roxburgh.

The high terraces (C_4, C_5, C_6 surfaces) from Cromwell to Tarras, and between Alexandra and Clyde, appear to be good irrigation propositions; they are, however, usually too high above any proposed dams to pump water economically on to the terrace. It has already been shown that the high terraces are lower in productivity and not really suited to a wide range of crops which could justify high-lift expensive water. Only Lake Hawea is high enough to supply cheap gravity water to some of the high terrace levels in the Upper Clutha, as can be seen in Table 4. The table shows the terrace heights adjacent to any proposed dams on the Clutha River between Beaumont and Lake Hawea. Terrace surfaces below the solid horizontal line can be reached by gravity races downstream of the dam. If 25 metres is taken as the economic limit for pumped water for pastoral irrigation, then the terraces below the dashed horizontal line can be reached. The C_0 surface roughly gives the river level at that spot. At Alexandra the C_4 terrace is at least 50

TABLE 4 — Approximate height of lake and terrace surfaces to nearest 0.5 m above sea level.

Surface	Beaumont	Roxburgh	Clyde	Cromwell	Luggate	L.Wanaka	L.Hawea
C_6	85.5	-	270.0	360.0	-	-	-
C_5	73.5	-	-	-	352.0	360.0	360.0
C_4	61.5	150.0	210.0	300.0	330.0	-	-
C_3	55.5	-	-	-	-	-	-
C_2	49.5	90.0	150.0	210.0	295.0	300.0	330.0
C_1	45.0	-	135.0	180.0	265.0	275.0	315.0
C_0	39.0	84.0	132.0	159.0	249.0	273.0	310.0
Headwater level:	69.0	129.0	162.0	192.0	268.5	273.0	342.0

metres above the dam crest at Clyde, and the C_6 terrace 100 metres. It may be possible at this point, however, to bring water in from the Manuherikia Valley.

RESEARCH

A common economic fallacy assumes that the maximum might be approached at a steady rate of increase comparable with that of the past 20 years. In fact, without further major scientific breakthroughs as effective as aerial topdressing and molybdenum fertilizers, the rate of increase of production could fall towards zero as problems of approaching the ultimate potential increase (Fieldes, 1969).

Although at the present time no scientific breakthroughs are apparent, this does not mean we should reject the possibility. The soils and climate are well suited to some crops, but the range of crops appears limited to what is grown at present. Soyabeans have been tried under irrigation, but once again they are frost tender and tricky to irrigate. Maize appears to offer some hope as a possible silage crop. although not as a grain crop (Table 5), and sunflowers would definitely be feasible. Rice has been tried but appears unsuitable.

TABLE 5 — Grain yields of trial maize plots. Waikato and Alexandra districts. (Relative maturity is the number of days for the crop to reach maturity under good growing conditions. The Alexandra temperatures are too low to provide sufficient heat to mature the later varieties and produce high yields as compared to the Waikato with its higher night temperatures.)

Relative maturity of variety:	80	95	110	115
Grain yield (kg/ha) —				
Waikato:	5900	7650	8000	9050
Alexandra:	3730	2960	1800	–

The use of bag nitrogen in stimulating irrigated and dryland pastures looks interesting after three years' work. The examples given in Table 6 indicate the responses to nitrolime applied at the rate of 50 kg of nitrogen per hectare every two months from September to April. Three years ago the low price of bag nitrogen seemed to offer a proposition of stimulating dryland production without irrigation. The most notable feature of this work was the increase in the dryland pasture production under a 400-mm rainfall to within 70 percent of the irrigated production. Unfortunately, soaring oil prices have meant a threefold increase in nitrogen price. As a commercial enterprise this work has lost all attraction, but the point still remains that bag nitrogen will give very large increases in pasture production under very low annual rainfall.

TABLE 6 — Effect of applied nitrogen on pasture production. Mean of three seasons 1971–72 to 1973–74. Annual rainfall 400 mm.

	Dry matter yield (kg/ha)		
	With added N	*Without added N*	*Response (%)*
Irrigated soils (3) :	13 400	10 200	32
Dryland soils(2) :	10 100	4 000	152

Irrigation is not limited to the semi-arid regions, and the potential for improving the efficiency of food production by supplemental irrigation in humid regions is large. There are areas, in the Lower Clutha in particular, where supplemental irrigation could be considered – that is, if there is any water spare.

Admittedly the above are just some trends, nevertheless climatically the area is carrying about as varied a range of crops as it can. Some of the higher-value crops could be increased in area if markets were available, and again this is a further reason for not flooding the better low-terrace soils of the warmer regions. These soils may be required in future.

ECONOMICS

It has been customary to say that if a dam is built at site *x* flooding *y* hectares then *z* dollars will be the annual sale value of electricity. This $*z* is then usually compared with the annual value of the agricultural produce from the flooded land. This gives an unreasonable bias in favour of power, as the electrical output is usually dependent on using a flow of water derived from a catchment many times the area of the agricultural land flooded. A fairer comparison would be to look at the returns per 100 m^3/h of water for power or, say, irrigation.

A comparison of the recently developed Lower Waitaki irrigation scheme and power proposals on the Clutha would be reasonable. This is given in Table 7. Data are derived from the 1969 Department of Agriculture economic assessment of the Lower

TABLE 7 — Annual sale value and capital costs, Waitaki irrigation and Clutha power.

Sale value —	
Dam proposal D, annual sale value per 100 m^3/h:	$3,700
Lower Waitaki irrigation, net gain per 100 m^3/h:	$4,400
Capital costs —	
Dam proposal D, capital cost per 100 m^3/h:	$21,300
Lower Waikati irrigation, capital cost per 100 m^3/h:	$6,200
Maniototo irrigation, capital cost per 100 m^3/h:	$11,000

Waitaki Scheme (Butler, 1969) and the Henderson (1972) Report. Prices are those at the time of the reports and do not allow for inflation.

Under a pastoral system the returns for 100 m^3/h for power and agriculture are very similar. The Lower Waitaki irrigation scheme is a fairly low-cost scheme when compared with most Central Otago schemes, so the proposed Maniototo scheme is given for comparison (1971 costs). Nevertheless, these concepts are put forward to emphasize the fact that per 100 m^3/h the sale value of the two products (power and agricultural) are comparable. Where the comparison is between power and horticultural land then it becomes obvious that power is second best. Capital costs are lower for irrigation projects.

This then brings us back to one of the introductory statements, where it was recommended "that suitable and acceptable criteria" should be developed upon which a change in land use should be based, particularly if horticultural land is involved. Six years after this statement was made no criteria have been laid down. Furthermore, the class-I and class-II soils are largely flat land, and here we have another scarce commodity which totals some 40 percent of the valley floor from Tuapeka Mouth to the lakes. It is here the people live (see Fig. 1), and if a commodity is scarce what price do you put on it? Finally, class-I soils constitute about 1 percent of New Zealand's area; how much of this should we lose?

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