

# LYSIMETER STUDIES AT THE SOIL FERTILITY RESEARCH STATION, HAMILTON

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This research station has undertaken a study of the water requirements of pasture in connection with its investigation of the system of overhead irrigation. No work had previously been published in New Zealand regarding the loss of water and soil nutrients in drainage water.

A lysimeter has been constructed and records have been obtained from it since the end of July, 1947. This paper summarises the investigations to date.

**Description of lysimeter:** The lysimeters at Rothamsted are each of an area of one thousandth of an acre and are three in number, viz., 20 inches, 40 inches, and 60 inches deep. The soil on each is kept free from plant growth. Similar lysimeters were constructed at Cawnpore and Puna in India some 40 years ago. Four were constructed at each place, two being 3 feet and two 6 feet in depth. On the Indian lysimeters records were obtained for both bare and cropped soils.

It was originally intended to build lysimeters of a similar area at Hamilton. Estimates of cost, however, were so prohibitive that plans had to be modified. Mr J. P. Heggie of this station drew up a design for a smaller lysimeter and the whole work was done by the staff of the station itself. Actual details of construction will be published elsewhere. Two concrete rings covered internally with bitumen 4 feet 3 inches in diameter and 3 feet deep were used in the construction. One ring was placed in position on a piece of undisturbed pasture. Soil was dug away around it and below the bottom edge in such a way that it could be forced down. Care was taken to keep it level. When the top of the ring was 3 feet below ground the second ring was placed in position on top, thus leaving a column of undisturbed soil 6 feet deep surrounded by the concrete rings. Actually the top ring extends 2 inches above the surface and holes for runoff water at  $\frac{1}{2}$  inch and 1 inch are provided. Pieces of  $\frac{1}{2}$  inch wood were placed in position between the rings in order to allow the introduction of a perforated steel plate between them. The soil below the plate was then

removed through an opening left in the side of the lower ring. Special supports were provided inside this to hold the weight of the soil in the top ring. A collecting funnel was then inserted below the perforated steel plate and soil was replaced around the outside of the concrete rings.

A special trench was provided to enable water samples to be collected. This was provided with adequate drainage and further lysimeters can be built alongside the trench when required later.

The surface area of the lysimeter is 1/3070 of an acre, about one third of the area of those at Rothamsted and in India.

The lysimeter has worked well. During the first summer the soil dried away from the walls at the top to some extent. Melted pitch was poured into the space so left around the wall.

The drainage has always been clear. Had there been any fissures, drainage water would have been muddy.

**Records:** Daily measurements of drainage flow are made and aliquot portions taken daily. Chemical analyses of the composite sample are made monthly.

Beginning from August, 1947, we now have records for over two years.

The table below shows the drainage water losses for the two years August, 1947, to July, 1948, and August, 1948, to July, 1949. In addition to the annual drainage loss for each year, figures are included for the drainage losses during the six wet months and for the six dry months. The six wet months were August, September, October, and May, June, and July.

TABLE I.  
Drainage Records.  
Soil Fertility Research Station.

Month	1947-48			1948-49		
	Rainfall inches per acre	Drainage inches per acre	Loss %age rainfall	Rainfall inches per acre	Drainage inches per acre	Loss %age rainfall
August	4.42	1.834	41	4.12	0.838	13.0
September	3.59	1.074	30	3.21	5.611	26.1
October	6.85	2.640	38.5	9.79		57.3
November	1.72	0.038	2.2	4.31	1.178	27.3
December	2.55	0.032	1.2	2.17		—
January	2.80		—	1.79	—	—
February	2.61	0.133	5.1	2.71		—
March	2.23		—	4.06	0.064	1.6
April	5.00	0.048	1.0	5.62	1.379	24.5
May	9.54	5.351	66.1	3.91	3.431	87.8
June	4.12	4.182	101.5	4.56	3.662	80.3
July	4.86	3.257	67.0	5.01	4.02	80.2
Total	50.29	18.59	37	51.85	23.63	45.6
Six wet months	33.38	18.34	55	31.20	21.01	67.3
Six dry months	16.91	0.25	1.5	20.65	2.62	12.7

### Losses of Minerals

The following table shows the losses of, minerals in each. of the two seasons :—

TABLE II.  
Losses in lbs. per acre.

A s	1947-48	1 9 4 8 - 4 9 .
CaCo <sub>3</sub> . .	109.19	65.36
MgCo <sub>3</sub> . .	113.57	53.96
K <sub>2</sub> So <sub>4</sub> . .	4 . 8 5	3.47
Superphosphate	1.04	.87
NaNo <sub>3</sub> . .	215.00	29.70

### Consideration of Results :-

(1) Drainage Water Losses: The drainage water loss for the two years amounted to 37 per cent. and 45.6 per cent. of the rainfall respectively.

It will be noted that in June, 1948; drainage accounted for 101.5 per cent. of the rainfall. This was due to very heavy rain at the end of May, which was reflected in increased drainage in early June.

The drainage losses at Rothamsted have averaged 50 per cent of the rainfall since, the lysimeters were built in 1870. There is little difference in the amount of drainage from the 3 lysimeters which are 20, 40, and 60 inches in depth. These lysimeters are, however, uncropped. A cropped surface would lose less by drainage, since the plants take up water.

At Cawnpore in India over the period 1905 to 1924, with a rainfall averaging 32.72 inches, the drainage from the 6 and 3 feet uncropped lysimeters amounted to 34 and 36.7 per cent of the rainfall respectively. When the lysimeters were under crop in 1909-10, 27 per cent, of the rainfall was lost in the drainage.

At Pusa in India over the 5 years 1906-1910, with a rainfall of 42.41 inches there was a loss of 24.6 and 29.5 per cent. of the rainfall from the 6 feet and 3 feet lysimeters respectively.

A second lysimeter is under construction at the Soil. Fertility Research Station, and it is proposed to keep this bare of crop. The difference between the amount of drainage from this and from that of the existing lysimeter will provide data regarding the amount of water taken up by the pasture.

Incidentally, this second lysimeter will be constructed with arrangements for recording soil moisture content instantaneously at every 6 inches depth.

Two special evapo-transpirometer tanks are also under construction in which the subsoil moisture level will be kept constant. One of these will be kept bare of plant growth and the other will carry pasture, which will thus be, assured of the optimum amount of water for growth. The bare tank will provide data concerning evaporation from a soil surface kept constantly moist. Evapo-transpirometers of this type have been used in Canada by Miss Sanderson.

**(2) Mineral Losses:** These are shown in Table II. above.

**Lime :** Rothamsted results indicate a loss of about 400 lb of carbonate of lime annually. In our Hamilton clay loam the losses appear much lower.

**Magnesia:** At Rothamsted the loss of magnesia as carbonate varies from 10 to 40 lb per acre per year. Our losses appear surprisingly high and further studies are being made of this matter.

Dixon and Taylor showed from a study of replaceable base figures from topdressed and untopped areas in the Waikato that associated with the continued use of superphosphates there have been definite losses of potassium and magnesium. In the case of magnesium they state that it is probable that this element, forced into the soil solution by means of gypsum contained in superphosphate, has been lost in drainage water.

**Potash and Phosphate:** The losses of these are small -and in line with the experience at Rothamsted and elsewhere.

**Nitrate:** Nitrate losses at Rothamsted averaged 212 lb per acre of sodium nitrate over a period of 20 years ending 1896-7, varying between 100 lb in the lowest rainfall year and 355 lb in the highest rainfall year.

In our first year the loss amounted to 215 lb per acre of sodium nitrate, but in the second year the loss was just under 30 lbs. Yet the rainfall was almost the same in the 2 years, 50.29. and 51.85 inches respectively. The following Table III. sets out the monthly losses of nitrate as lbs. per acre of  $\text{NaNO}_3$  for the two years.

T A B L E   I I I .

Losses of  $\text{NaNO}_3$  in Drainage Water-Lbs. per Acre.

	1947-48	1948-49
August	48.32	12.12
September	24.61	3.00
October	38.03	1.24
November	0.59	1.60
December	0.59	—
January		—
February	0.37	
March		4.86
April	0.43	1.03
May	51.92	2.74
June	36.83	2.11
July	13.90	1.00
Total :	215.00	29.70

During the war years the land had been cultivated for vegetable growing, and it may be that there were large accumulations of nitrate in the surface when the land was put down in grass. Thus in August, September, and October, 1947, large amounts of nitrate leached away in the drainage water. During the period November, 1947, to April, 1948, there was very little flow from the lysimeter and consequently little loss of nitrate. When the lysimeter again ran freely in May, 1948, further large amounts of nitrate were washed out. The lysimeter flowed freely in June, July, and August, by which time the nitrate in the soil appears to have been almost completely leached out. During the summer period, November, 1948, to February, 1949, there appears to have been no further nitrate accumulation in this soil, as only small amounts of nitrate appeared in the drainage water in spite of copious rain and free running of the lysimeter.

It appears, therefore, that little nitrification is taking place in this Hamilton clay loam under pasture beyond any amount which is taken up by the grass.

Studies of nitrate content of various soil types were carried out by the Soil Survey Division during investigations into the cause of facial eczema. It is interesting to note that little nitrate was produced in Hamilton clay loam in conditions under which large amounts were produced in the lighter soil types of the Waikato.

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### An early New Zealand Lysimeter :

Mr Grimmett called my attention to the fact that in 1927 a lysimeter was built by Mr Aston and himself in pumice soil on Mr Brain's farm at Kaharoa. It was rather different in construction from that in use at the Soil Fertility Research Station. An undisturbed column of soil 4 feet deep was isolated and a cement culvert 4 feet long and 3 feet in diameter was fitted over it. The culvert was previously tarred internally. The soil column was then cut away at the base by drawing No. 8 wire across the bottom of the culvert. Wire strainers were used to draw the wire through. A specially prepared funnel-shaped concrete base had meantime been placed in position deep in the ground. This contained a filtering layer of quartz pebbles which had been cleaned with hydrochloric acid. The soil column in the culvert was then placed in position on the concrete base, the point being made watertight with pitch. An excavation below the base was made in order to insert a glass carboy to collect drainage and a narrow trench was provided to enable this to be removed and replaced. When the lysimeter was finished the top of the soil within it was level with the surrounding pasture. No data were published concerning the flow from the lysimeter, except for short notes in the Annual Reports of the Department of Agriculture for 1930 and 1931, which merely referred to the fact that application of superphosphate to the surface soil had not led to loss of phosphate in the drainage water. However, when the lysimeter was first constructed and before application of superphosphate, it was reported that the drainage water contained no phosphate (October, 1928). After application of superphosphate the drainage water contained the following amounts of phosphate:-

	$P_2O_5$ parts per million
November, 1928 . . . . .	.0053
June, 1929 . . . . .	.328
July, 1928 . . . . .	.31

No further observations appear to have been carried out on this lysimeter until Mr Grimmett and I visited Mr Brain's farm in June of this year. We found that the cement culvert was exposed to a height of about 2 feet above the surrounding pasture. This may have been partly caused by tramping of stock around the lysimeter, but largely by soil having been washed

away. The lysimeter was built on slightly sloping ground, the trench being on the lower side. Soil washed away from the upper side had completely filled the trench. The site of the old trench was dug out in order to examine the bottom of the lysimeter. The lysimeter appeared to be in good order and clear drainage water was flowing from the exit of the concrete funnel. A bottle was placed in position and Mr Taylor made a collection of the drainage water at the end of June. The table below shows the composition of this drainage water in parts per million. For the sake of comparison, figures are also given for June drainage from the lysimeter at the Soil Fertility Research Station :—

	Parts per million				
	CaO	MgO	K <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	NO <sub>3</sub> as N
Kaharoa	15.1	1.63	5.52	0.04	3.32
Hamilton	3.76	3.26	0.57	0.09	0.54

One cannot generalise from such scant data. It is interesting, however, to note that the loss of magnesia in relation to lime is far less at Kaharoa than at Hamilton. The loss of potash in relation to lime, however, seems surprisingly high at Kaharoa.

Presumably the soil has been losing lime, magnesia, and potash throughout the 22 years since the lysimeter was constructed, and the losses provide a measure to some extent of the rate of weathering. It is proposed to make regular analyses of the Kaharoa drainage water.

### Evaporimeter Studies :

The lysimeter is situated within a few yards of an evaporimeter which is part of the equipment of the meteorological station. The evaporimeter is a free water surface from which daily readings are taken of the amount of water evaporated. By deducting the amount of drainage from the lysimeter, one obtains the amount of water which passes away into the atmosphere from the pasture surface. Some of this is transpired through the leaves and some is evaporated from the soil surface.

For the period May 1, 1948, to April 30, 1949, the loss of water from the free water surface amounted to 32.2 inches. The loss from the pasture surface on the lysimeter amounted to 31.6 inches, which is 98.3 per cent. of the previous figure.

During the hot dry summer months- the lysimeter surface loses little water, as is only to be expected. In March and April, 1949, and May and July, 1948, the losses from the surface of the lysimeter were far greater than from the free water surface, being over  $2\frac{1}{2}$  times as much in April, 1949, and twice as much in May, 1948. In October, 1948, a period of active growth, the loss from the lysimeter surface was 50 per cent. greater than that from the free water surface.

Recent work at Rothamsted dealt with the measurement of evaporation from open water surfaces, and from short grass with a water table near the surface, and also from bare soil. The results showed that the total annual water losses from the short grass is about three-quarters of that from the open water surface. Further, the indication is that evaporation from a tall crop may be about the same as that from short grass,

The Rothamsted work also shows that drying conditions at the surface of bare soil, initially at field capacity, tend to set up a liquid movement from below to the surface. If the drying rate is small, as it is in winter, the flow of soil water can keep pace with it, so maintaining a steady evaporation rate very nearly equal to that from an open water surface and calculable from weather data. If the drying rate is great, the flow of soil water cannot keep pace with it, and the top layer of soil dries out, even though moist soil conditions obtain only a few millimetre away.

When the new lysimeter and the evapo-transpirometers referred, to earlier are constructed, further information on these points will be obtained under conditions obtaining in New Zealand.