VARIATIONS OF RAINFALL FREQUENCY IN RELATION TO EROSION IN EASTERN HAWKE'S BAY

P. J. Grant*

SUMMARY

Erosion phenomena and their relations to rainfall are discussed under two categories: (a) massive movements such as slips, slumps and earthflows, and (b) general surface soil losses. Massive earth movements are related to periodic, exceptionally heavy rainfalls. Surface-soil loss may occur with every run-off producing rain and therefore can be related to the frequencies of the larger rains.

Maximum daily rainfalls recorded at 16 stations were used to determine the relative storminess of each decade since 1900. On this basis the periods of greatest regional massive erosion potential were, in descending order of magnitude: (1) 1931-40, (2) 1911-20, (3) 1951-60 and (4) 1961-5. The average massive erosion potential for 1931-60 was greater than that for 1901-30.

The frequencies of daily rainfall sizes at Napier since 1870 were analysed by seasons and important cycles and trends were revealed. These can be validly applied to Eastern Hawke's Bay. For each season the broad periods of greatest soil-loss potential are given; a combination of seasonal results indicated that the annual periods of greatest soil-loss potential, in descending order of magnitude, were: (1) 1890s, (2) 1870s, (3) mid-late 1930s, (4) early 1900s and (5) 1920s.

Some implications concerning land management and hydrological parameters are briefly discussed.

INTRODUCTION

Eastern Hawke's Bay is an arbitrarily defined region; clearly defined limits are not important. It is taken as extending along the coastline from about Wairoa to Porangahau. In the southern portion it extends inland for 25-30 miles, and where it borders Hawke Bay the zone is narrower (Fig. 1).

* Ministry of Works, Napier.

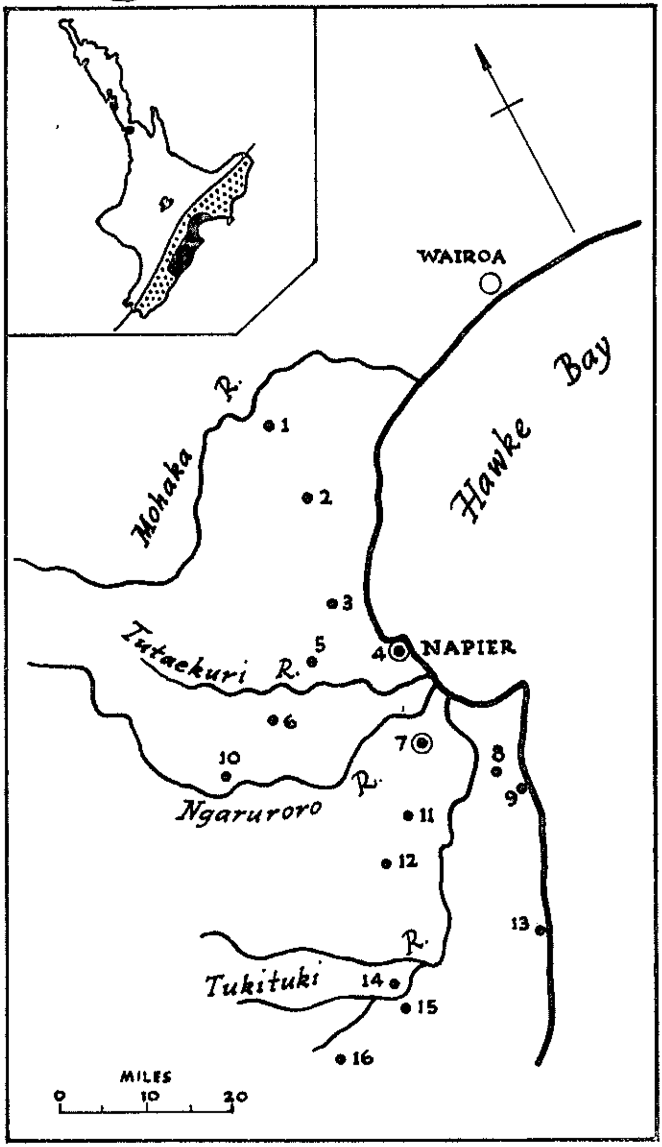

Fig. 1 (inset) — NORTH ISLAND. Eastern Hawke's Bay is shaded. East Coast area (De Lisle, 1961) is stippled.

Fig. 2 — RAINFALL STATIONS. These are numbered:

1. Maungaharuru
2. Tutira
3. Hedgeley
4. Napier
5. Rissington
6. Sherenden
7. Hastings
8. Mokopeka
9. Waimarama
10. Whanawhana
11. Poukawa
12. Te Aute
13. Aramoana
14. Mt Vernon
15. Waipukurau
16. Oruawharo

The geology of the region has been presented by Grindley (1960) and Kingma (1962), and soils have received broad treatment (Anon., 1954). Except for limited areas of Upper Cretaceous rocks, the region is composed of Tertiary and Pleistocene mudstones and sandstones.

Erosion phenomena and their occurrences are known to have been observed and recorded by Guthrie-Smith (1926), Cumberland (1944) and Campbell (1945) and in a summary of floods (Anon., 1957) further useful information was given. Subsequent observations confirm earlier views. Massive land instability and erosion are closely related to storm-rainfall amount, duration and maximum intensity, and the effects of a storm are related also to antecedent soil conditions. More detailed elaboration here would amount to repetition of ideas propounded by others and well presented by Bennett (1939), as the primary relations between precipitation characteristics and erosion are universal.

Average annual rainfalls generally range from 30 to 50 in., and in local areas they exceed 70 in. Point rainfalls frequently exceed 10 in. a day. During the storm of March, 1924 (Kidson, 1930) Rissington recorded 20.14 in. in 10 hours (see Fig. 2). Some other heavy rainfalls are tabulated in the preceding references.

Erosion phenomena may be subdivided conveniently into (a) massive movements of soil and sub-strata and (b) soil loss by sheet and incipient gully erosion. The former is spectacular, the latter is insidious. Massive movements provoke early attention, but gradual soil surface wastage which inevitably follows land development — continues almost unrecognised, yet this insidious wastage over a long period might well account for a greater regional soil loss than do the catastrophic events.

Land instability and soil loss are, we recognise, closely related to the impact of exceptionally heavy rainfalls, but the less readily detectable soil losses are geared to the nature of the rainfall — its composition, both quantative and qualitative, for each season. Erosion phenomena and rates vary in degree on an areal basis in accord with variation of rainfall characteristics. Moreover it is logical that if a time series indicates marked changes in rainfall regime, then comtemporaneous changes of erosion potential must have occurred.

The history of the various effects on the soil mantle of land settlement and development is not the story of man's deeds alone — it must be viewed against the changing pattern of climate. Although man and animals have accelerated overall soil wastage it is certain that some past periods were climatically more conducive than others to erosion. In short, it is axiomatic that to obtain a balanced picture of cultural effects we must first understand the natural order. This, essentially, is the theme of the information that follows.

REGIONAL MAXIMUM RAINFALLS

For each of 16 rainfall stations (Fig. 2), having a total coverage of approximately 2,500 sq. miles, the eight highest annual 24-hour maximum rainfalls since about 1900 were tabulated and assigned to decades on the basis of year of occurrence. The results are in Table 1.

TABLE 1 — Frequencies of the eight highest annual 24-hour maximum rainfalls at 16 stations (Fig. 2).

Period	Number of Storm Years (A)	Number of Storm Occurrences (B)	A/B	Larger Storms Recorded
1901-10	5	8	0.63	1910, at 3 stations
1911-20	7	29	0.24	1917, at 10 " 1919, at 6 "
1921-30	3	11	0.27	1924, at 6 "
1931-40	7	41	0.17	1938, at 16 " 1936, at 13 "
1941-50	6	13	0.46	1950, at 4 "
1951-60	7	17	0.41	1953, at 6 " 1955, at 5 "
1961-5	2	9	0.22	1963, at 7 "
1901-65	37	128	0.29	

Broadly, the lower the ratio A/B, the more widespread were some of the storms of the period, but to assess relative storminess the frequency values themselves must also be considered. The decade 1931-40 is outstanding as the stormiest period in the region since 1900; 1911-20 ranks next. The period 1951-60 may be ranked third, and the record to date indicates that the current decade, 1961-70 is likely to rank fourth.

If a much larger area were considered the picture might alter somewhat, but for Eastern Hawke's Bay it is essentially true — moreover it convincingly demonstrates that marked variations in periodic storminess have occurred since 1900.

The graphical trends of East Coast rainfall indices (de Lisle, 1961) show that about 1930 there was a major trend reversal — from rainfall decrease to increase. Adopting this turning point, it is found that of the 16 stations used, 10 recorded their extreme maximum 24-hour rainfall after 1930 (actually after 1935.) In addition, if the 60-year period, 1901-60, is divided equally (Table 1) there were 15 storms and 48 storm occurrences registered for

1901-30, and 20 storms with 71 occurrences recorded for 1931-60. The latter 30-year period was stormier than the preceding one, and the indications are that this rather higher level of average regional storminess still persists.

From a study of channel regime changes in the Upper Tukituki River Catchment, the author (Grant, 1965) postulated that small-area rain storms have increased markedly in intensity since the 1930s. It was also stated that the increase in storm intensity pertained particularly to rainfalls with durations of a few hours; certainly to periods shorter than a day. Hence, daily rainfall amounts may be of limited use for either determining or checking such trends.

Although daily rainfall values may be of limited use, the above preliminary analysis over a limited area has yielded results which harmonise with, and therefore strengthen, the postulate quoted. The general agreement is of special interest because the Tukituki River rises on the Ruahine Range where the rainfall regime differs greatly from that near the East Coast because of the much greater influence of the westerly rains. Perhaps this broad agreement in the trend of storminess between different rainfall regimes is sufficient basis for postulating that the same trend has been operative over a very much greater area than that now considered. Records exist to test this postulate.

The magnitude range (3.3-17.9in.) of the daily values (Table 1) classes these events as primary causes of the more spectacular and catastrophic erosion forms, viz slipping, slumping, earthflow and major gullying. Logically, the more stormy a period is, the greater is the potential, if not the actual, erosion. Therefore we may classify the decades, since 1900, of greatest erosion potential — in descending order of greatness:

1. 1931 - 40
2. 1911 - 20
3. 1951 - 60
4. 1961 - 65

The average erosion potential for the period 1931-60 was greater than that for 1901-30; furthermore the regional erosion potential from 1951 to the present appears to be higher than was that for the periods 1901-10, 1921-30 and 1941-50. For all periods it is probably safe to substitute "actual" for "potential".

The erosion period classification applies to the region considered as Eastern Hawke's Bay (Fig. 1) and therefore in any portion of the region the periodic rank of erosion potential may vary, e.g., between Napier and Maungaharuru (Fig. 2) the period 1921-30 would rank highly owing to the 1924 storm.

The periods listed as being of greatest massive erosion must also have been the periods when the greatest quantities of colluvial-alluvial materials were deposited — as accumulations on easy-sloping valley floors and flats and, bordering larger streams, as depositional terraces. Many of these deposits are in evidence today and form distinct stratigraphic time units useful for the assessment of subsequent land history.

When such a powerful causative factor as storm rainfall has varied so greatly during the major phase of European land development, it is obviously impossible, in ignorance of such changes, to assess correctly the effects of land development and management practices on massive erosion phenomena.

DAILY RAINFALLS AND EROSION

Variations in the frequencies of rainfalls of various sizes, other than extreme values, may either reduce or increase the erosion potential which is related to the vigour and density of protective vegetation and to the ability of surface run-off and streamflow to transport sediments. This form of erosion is insidious; it occurs to some degree with every rain that produces run-off, but it frequently proceeds unrecognised and unchallenged for long periods.

Small amounts of rain in a day contribute very little to the erosion problem. In fact, on pastoral land, frequent small rains — particularly in the growing season — produce a more vigorous and denser plant cover and thus afford a more efficient buffer against soil loss from subsequent larger rainfalls in autumn and winter.

Large daily rains, greater than say 1.0 in., also contribute to plant growth but, especially on heavy soils which are widespread in the region, produce greater run-off quantities. Increased volumes of run-off have the potential to cause sheet and gully erosion.

During most summers in the eastern portion of Hawke's Bay, upper soil horizons become dry enough to impair the vigour of pasture plants. This feature, in conjunction with necessary pasture utilization by animals, means that for summer it is logical in the first place to relate erosion potential to the frequency of large rains, noting that soil loss will be even greater when the frequency of smaller rains is low.

For autumn the same primary relation to soil loss potential can be adopted but a secondary relation must be considered, viz the soil—plant status of the preceding summer. In short, if the erosion potential of the preceding summer was high then this carries over as a positive influence on soil loss in the autumn. The converse relation also holds.

Winter soil-loss potential may be considered in relation to the frequency of larger rainfalls, although there may be a secondary carry-over effect from autumn.

Soil loss potential in spring, especially later when it frequently becomes very warm and dry, can be related to rain-size frequencies as for summer.

Of course, superimposed upon this sequence of relatively unobtrusive soil losses is the occurrence of extreme rainfalls, as discussed earlier, which produce massive earth movements. Furthermore, for some time after such an event has occurred, it will exert a considerable positive influence upon the magnitude of total soil losses. Relative soil losses will nevertheless remain closely related to the frequency of the larger rains at the time.

DAILY RAINFALL FREQUENCIES

The frequencies of daily rainfalls recorded at Napier since 1870 have been analysed.

Homogeneity tests indicated high levels of reliability for both rainday numbers and rainfall amounts since about 1905. Prior to 1905 deficiencies are indicated which have most likely resulted from neglecting to measure light daily rains (this is a tendency today at many stations). The present broad study is, however, more concerned with larger daily rainfalls, in excess of 0.50 in. (see later) and the recorded frequencies of these since 1870 may be reliably accepted.

For the period 1890 - 1961 Napier annual rainfall indices (annual rainfalls expressed as percentages of the 1911-40 mean) correlate quite highly (r* = 0.84, significant at greater than the 0.1% level) with the mean indices for the East Coast area (de Lisle, 1961). Although this is of little value in itself as a check on the homogeneity of the Napier record, it indicates that the findings and implications of the present study may have valid qualitative application to the East Coast area, and particularly to Eastern Hawke's Bay.

Napier daily rainfall amounts have been classified into six size groups: (a) 0.01 - 0.20 in., (b) 0.21 - 0.50 in., (c) 0.51 - 1.00 in., (d) 1.01 - 1.50 in., (e) 1.51 - 3.00 in., and (f) greater than 3.00 in. In each year the frequency of rains in each size group was tabulated on a seasonal basis, the seasons being: summer (Jan., Feb., previous Dec.,), autumn (Mar., Apr., May), winter (June, July, Aug.) and spring (Sept., Oct., Nov.). Because daily rains 3.00 + in. are infrequent at Napier this size group was combined for analysis with group (e) to give a group 1.50 + in.

* r = Pearson's coefficient of correlation.

For each season a diagram is given of yearly rainfall amounts and a series of five diagrams of frequencies of raindays for the different rainday size groups. No real attempt is made to define the statistical significance of the many fluctuations exhibited in the diagrams, because for practical application there are no absolute criteria. Moreover, extreme values which may have no statistical significance can produce marked observable effects.

Cumulative percentage departure diagrams (not presented) were used as a check on the chronological determination of trend turning points.

Climatological implications and relations are to be discussed in a further communication.

FREQUENCY AND EROSION CHANGES

Using the criteria already outlined, the broad periods of high erosion potential are summarised.

Spring

The most marked and persistent seasonal frequency changes are indicated in spring (Fig. 3B) for the larger rain groups. Rains, 1.50 + in., attained their highest frequencies during 1893-1905. The period 1893-1920 has an average frequency value of 0.64 for these rains; 1921-63 has an average value of 0.16.

The 1.01 - 1.50 in. rains exhibit parallel trends; 1890 - 1920 has an average annual frequency value of 0.71, while for 1921-63 the value is 0.49.

Undoubtedly, during 1893-1920 the erosion potential was generally higher than it has been since, and the period 1893-1905 had the greatest erosion potential since 1890 — possibly since 1870.

Because rainfall amounts (Fig. 3A) show no distinctive trends, it is likely that quantitative increases from smaller rains have balanced decreases from larger rains.

Summer

Larger summer rains show pronounced frequency fluctuations for quite long durations (Fig. 4B). The prevailing tendencies are for larger rains to decrease in frequency and for smaller rains to increase.

The periods of greatest soil loss potential were, in descending order of greatness:

1. mid 1870s
2. early 1890s
4. late 1910s to early 1920s
5. late 1950s to early 1960s
3. mid to late 1930s

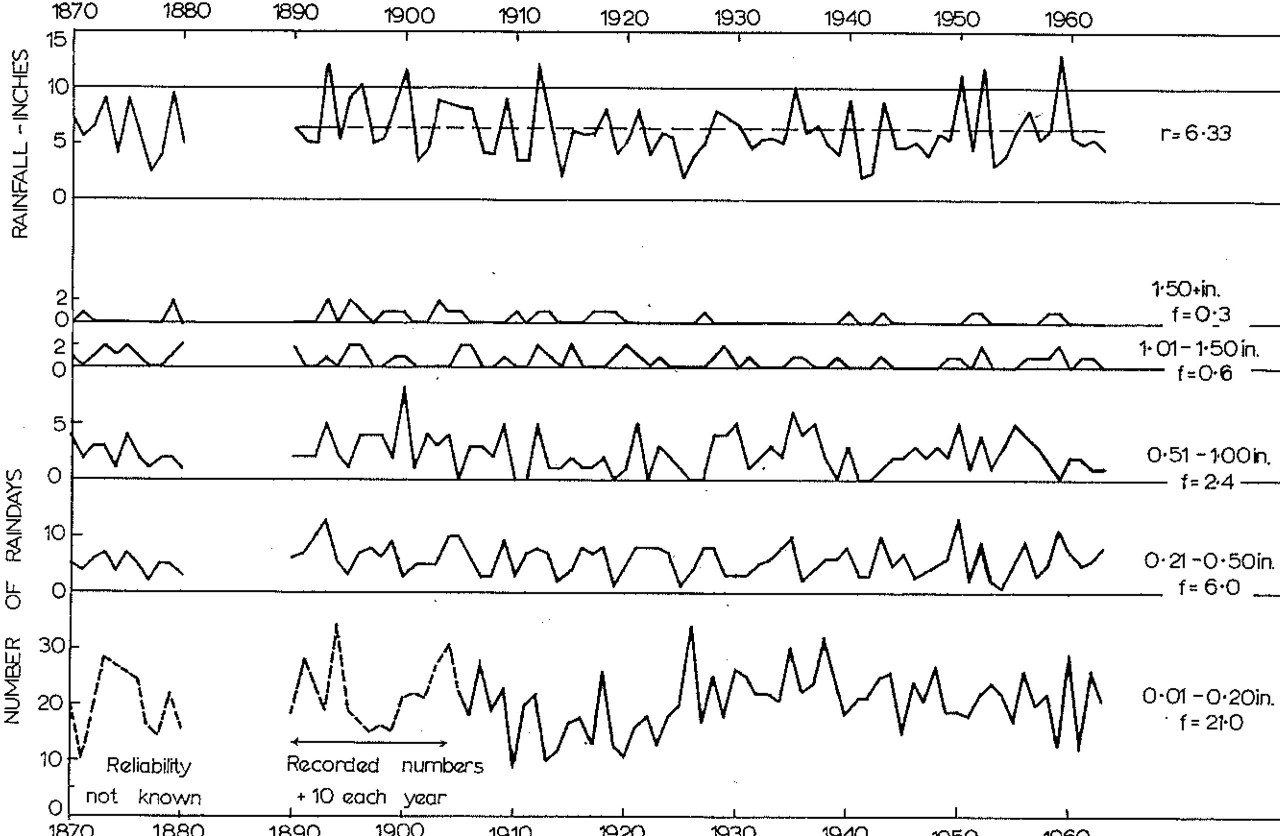

Fig. 3 — SPRING: (A) RAINFALL AMOUNTS (inches); r is the mean value for 1890-1963. (B) NUMBER OF RAINDAYS; f is the mean frequency for 1890-1963, 1905-63 for 0.01 - 0.20in. rains.

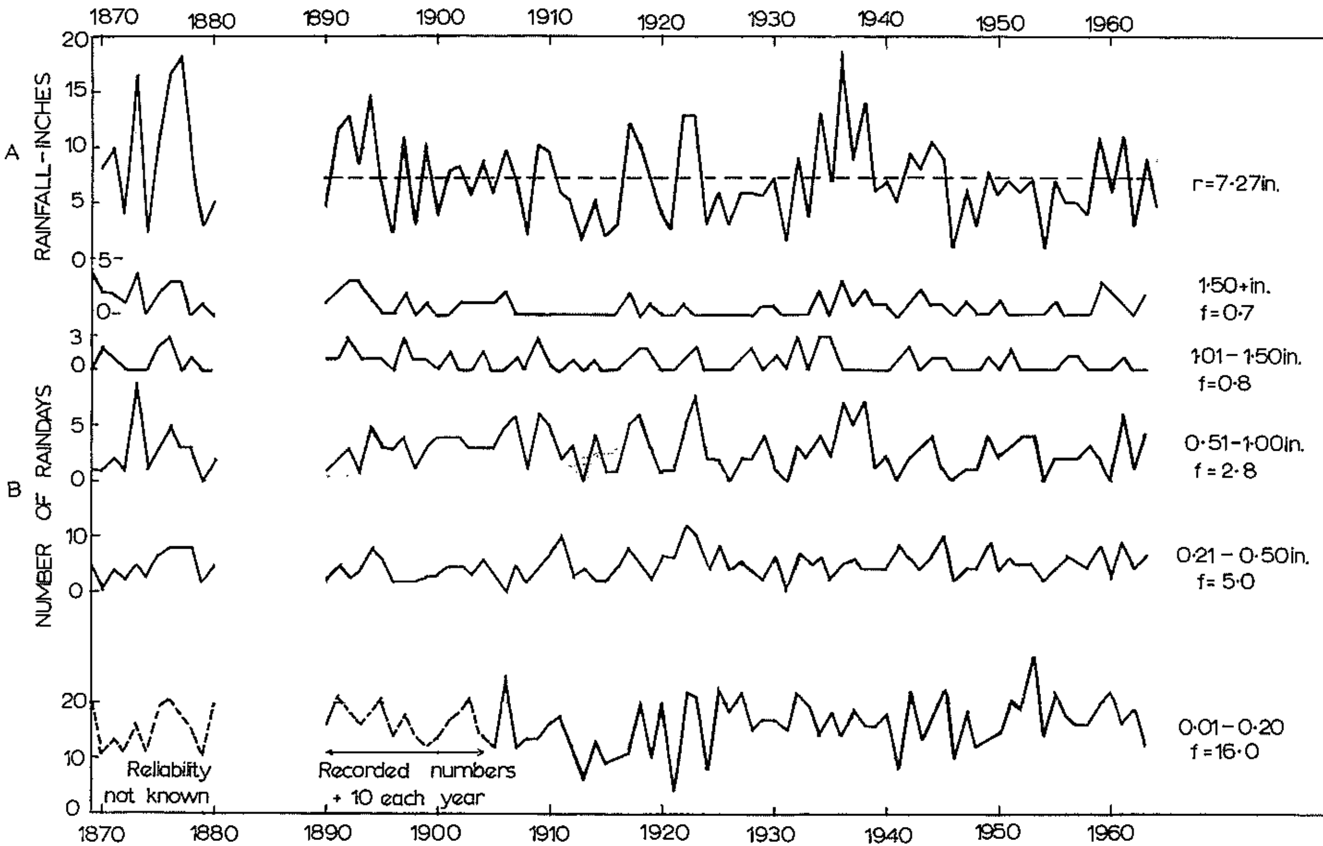

Fig. 4 — SUMMER: (A) RAINFALL AMOUNTS (inches); r is the mean value for 1890-1963. (B) NUMBER OF RAINDAYS; f is the mean frequency for 1890-1963, 1905-63 for 0.01 - 0.20in. rains.

Autumn

Frequency variations of autumn rains (Fig. 5B) are less pronounced than are those of spring and summer, nevertheless some trends are evident since 1890. Between 1911 and 1932 the 1.50 + in. rains reached their lowest frequency and failed more consistently. The average annual frequency of the 1.01 — 1.50 in. rains has declined since about 1930 and their variability has decreased.

Judged by the higher frequencies of the larger rains the spells of greatest soil loss potential were in the 1890s, and around 1910. No other periods of reasonable duration are outstanding, but in certain years, such as 1874, 1879, 1880, and in the 1930s and 1940s, soil losses must have been very great.

Winter

Winter is the wettest season on the average and for the larger rains it has the least degree of long-term frequency variability, but some trends are indicated (Fig. 6B).

The broad periods of greatest erosion potential appear to have been, in approximate order of decreasing magnitude:

1. 1890s
2. early 1900s
3. mid-late 1930s
4. mid 1920s
5. mid 1950s

The winter of 1879 must have produced large soil losses.

Yearly Periods of Great Erosion Potential

Since 1870, and neglecting the period 1881-9, individual seasonal assessments of periods of high erosion potential have been combined to produce estimates on a yearly basis. In descending order of erosion potential the broad annual periods are:

1. 1890s
2. 1870s
3. mid-late 1930s
4. early 1900s
5. 1920s

Reference to Table 1 shows that both approaches agree in labelling the 1930s as the period of greatest regional erosion potential since 1900. But it is important to remember that camouflaged by the annual pattern are the seasonal idiosyncrasies which do not always accord with each other on a time basis.

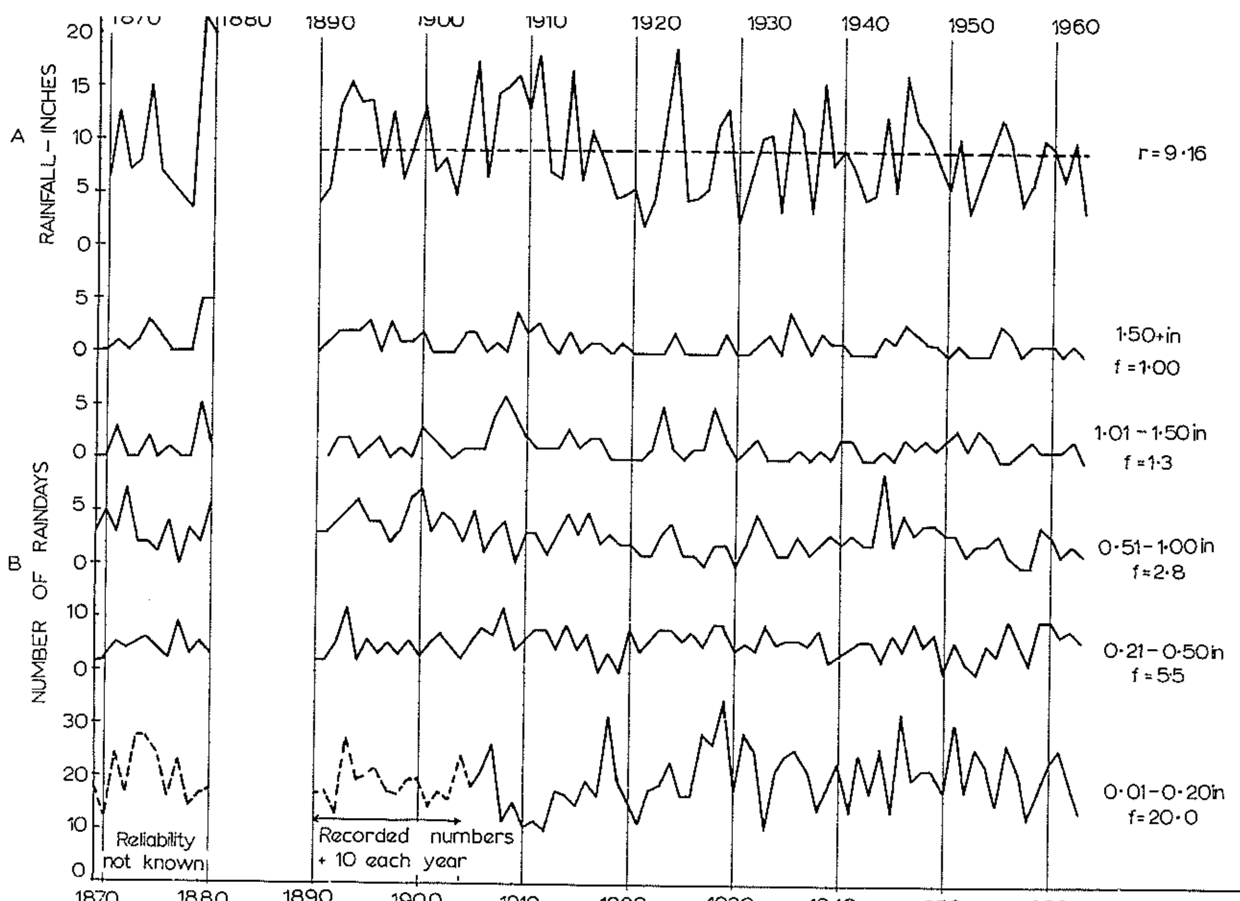

Fig. 5 — AUTUMN: (A) RAINFALL AMOUNTS (inches); r is the mean value for 1890-1963. (B) NUMBER OF RAINDAYS; f is the mean frequency for 1890-1963, 1905-63 for 0.01 - 0.20in. rains.

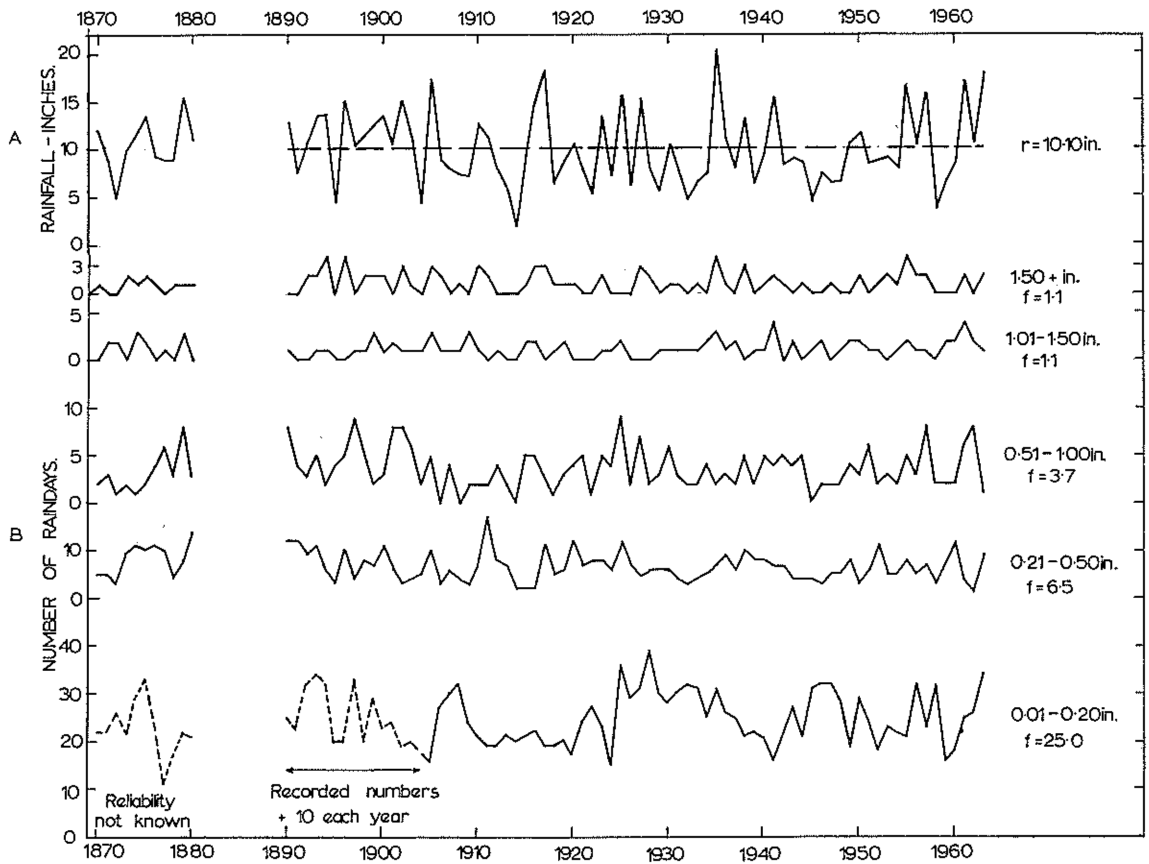

Fig. 6 — WINTER: (A) RAINFALL AMOUNTS (inches); r is the mean value for 1890-1963. (B) NUMBER OF RAINDAYS; f is the mean frequency for 1890-1963, 1905-63 for 0.01 - 0.20in. rains.

EROSION AND LAND MANAGEMENT

Some indications have been given of the important periodic fluctuations of erosion potential that have occurred since the advent of Europeans and exotic animals.

The present decade, judged by daily rainfall quantities (Table 1) and by the frequencies of larger rains in summer and winter, has a moderately high regional erosion potential. Periods of far greater erosion hazard have occurred during the last 75 years, however, and they will surely recur. Therefore, notwithstanding the occurrence of tranquil periods, current soil conservation policy in Eastern Hawke's Bay should be contrived to cope with an erosion potential somewhat higher than that of the present.

That climate is seldom constant for long — that some periods are more conducive than others to soil erosion and flooding is an axiom that must be remembered when broad attempts are made to compare the effects of different forms of land management; otherwise assessments may be seriously in error.

Hydrological determination, from short-period records, of long-term values for soil loss and sediment yield, and for various flow parameters, is a hazardous task unless the variability of each factor in response to variations of rain size frequency is reasonably well-known. Until these relations are known it is impossible to determine with reliability the effects of cultural changes on the sediment and streamflow patterns.

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