INTRODUCTION AND REVIEW

It is my duty, as chairman of the Forestry Section of the 9th New Zealand Science Congress, to inflict upon you a chairman’s address. It is a duty I cannot hope to avoid. The only crumb of comfort that I have been able to find is that, within certain well-defined limits, I am free to choose my own subject. Mark you, I am not absolutely free! I must, if possible, relate what I have to say to one or other of the topics set down for discussion. I should, if possible, speak from experience, contributing either something new or some worth-while and constructive review of past work. My address should be stimulating and thought provoking, possessing at the same time, at least a modicum of real entertainment value.

These, Ladies and Gentlemen, were the thoughts that crossed my mind when I was asked to take the chair— at a time, I might add, when I was so far from New Zealand that I had no reasonable opportunity of refusing the honour. Now I must admit to a measure of worry in the matter, a degree of concern that was only partially overcome when I discovered that one subject listed on our agenda was that of protection-forest management. At least, therefore, I had one ready-made subject on which to speak; not, I would stress, a ready-made subject on which to speak authoritatively, but nevertheless a subject to which I have given a good deal of thought and on which I might hope to speak with inner conviction. If I could not speak with contagious conviction on this subject, then I could not do so on any subject.

The high alpine watersheds and the watershed protection forests of New Zealand have always loomed very large in my life—from the time when, as a small boy, I tagged along in the field behind my father, Leonard Cockayne, George Simpson, J. S. Thomson, and other botanists of a generation now gone from us, up to recent years when research in watershed management has become a full-time career. I do not want to bore you with biographical details. These can be left to an obituary writer when the time comes. The only point I want to make is that my experience of the mountains is lengthy though it may not be deep—billy boy to the botanists of the twenties, mountain-eering and field collecting for geologists in the thirties, work on the

*Senior Principal Scientific Officer, Forest Research Institute.
National Forest Survey from 1945 to 1955, and protection-forest research since then. These have been years during which I have learnt a lot, though not perhaps as much as I should have done had I grasped fully all the opportunities that offered; but then, at no time did I ever intend to become a student of watershed and protection-forest management. This was one of those things that just happens. All the same, I did learn a lot.

**A Mountainous Land**

The things I have learnt, I can sum up for you very briefly. I have learnt that New Zealand is an excessively mountainous land. You may say that you know this; but I say that few New Zealanders really know it. Most New Zealanders are lowlanders, vaguely aware that there are mountains in the background, or aware only of the mountains as scenery, as a place for alpine exercises, as a place for unlimited hunting, or as the abode of legendary gentlemen called runholders. There is no general acceptance of the harsh facts of life as it must be lived in an excessively mountainous land. There is no general appreciation of the fact that upon sane management of the mountain lands depends the safety and continued productivity of the lowlands, in effect the future of all lowlanders. The mountains are not just a scenic backdrop to our lives, a place for sport and recreation, or a source of fine wool. They are all these things, but, over and above this, they are the source of hydro-electric power, and a source of water for domestic, industrial, and agricultural use. In truth, the mountains and all things that happen in the mountains impinge directly and inescapably upon our comfortable lowland existence.

This was the first lesson that I learnt. It is my belief that it is well past time for it to be absorbed into the day-to-day thinking of every New Zealander. The time is overdue for the awakening of all New Zealanders to the size and significance of their stake in the mountain lands. We should not continue with habits of thought suitable only for the inhabitants of a gentle land, regarding the mountains as some distant Switzerland to which we can resort for pleasure. These habits of thought, stemming perhaps from our English forefathers, contain the seeds of disaster. The mountains rise from our doorsteps, whether we like it or not. Everything that happens in the mountains affects us, and will affect our children and our children's children, whether we like it or not. If we want things to go well, it is up to all of us to take a vigorous and informed interest in these things, not just an interest in one single facet of the truth but a sincere interest in all facets as they stand in complex interrelationship.

**The Certainty of Trouble**

The second thing I have learnt is that the probability of trouble in management of the mountain lands of New Zealand is very great. For any mountain lands, anywhere, but particularly in respect to
virgin mountain lands, we must expect trouble as an inevitable consequence of human interference—of the adoption of new forms of land use, of the introduction of new species of animals, or of any other disturbance of the state of balance. This probability becomes a certainty wherever the mountains are young and very steep, wherever bedrock is weak or strongly shattered, wherever soils are shallow, infertile, or of weak structure, and wherever climate runs to extremes. I might express this in another way by stating categorically that the faster the rate of normal geological erosion, the greater is the probability that erosion rates will accelerate after any interference with the natural state of balance; or again, that the greater the natural flood hazard, the more will this hazard be enhanced by mismanagement of the watersheds.

If we now turn to study of our own mountain lands, we find that, with few exceptions, the entire range of factors suggestive of trouble must be faced. Our mountains are young and very steep, bedrock is generally weak or strongly shattered, soils are very shallow, infertile and structurally weak, and mountain climates run to violent extremes. In addition, there are very strong grounds for the belief that the native vegetation was, and is, exceptionally tender in the face of animal grazing, browsing, and trampling. I cannot enter into these matters in detail. There is need for much further study before we attain a complete or adequate understanding of the situation. But I am personally convinced that further study will serve only to confirm the statements that I have made.

Excuses are Inadequate

To repeat: any one of the factors mentioned, operating alone, would be a certain cause of trouble. Taken together, as we find them together throughout much of our mountain country, they are deadly. From the day the first fire was set in the mountains, from the day the first grazing and browsing animals were introduced, there could be no escape from trouble. We cannot escape it by hiding our heads in the lowlands. We cannot escape it by ascribing all our difficulties to the known fast rate of normal geological erosion. We cannot escape it by proclaiming that each and every flood to surpass peaks achieved by preceding floods is the result of some quite exceptional weather sequence. We cannot yet draw any sharp line of demarcation between normal and accelerated erosion. The probability is that we shall never be able to do this to our complete satisfaction. Likewise, we are unable to calculate the degree to which flood peaks have risen, or the extent to which stream channels have aggraded, as a direct result of watershed mismanagement. These calculations, also, we may never be able to make satisfactorily. But we do know that acceleration of erosion was inevitable, that aggradation of stream channels was inevitable, and that gross modification of stream-flow patterns was
inevitable. The fact that we cannot present pretty calculations must not be used as an excuse for inaction.

**Time is Short**

I come now to the third main lesson that I have learnt. This is, that there is not a great deal of time to be wasted if current downward trends in the condition of the watersheds are to be halted soon enough to permit repair at reasonable cost. We cannot afford to wait until the damage done is spectacular or obvious, though it must be stated that this stage has already been reached in many important river catchments. Immediately we lose the primitive soil mantle, immediately we enter a new cycle of erosion marked by development of new erosion forms and processes, whenever and wherever climatic and other physical forces conducive to erosion gain the upper hand over biological forces restraining erosion, then the cost of repair leaps upwards astronomically. I must stress this point. *We cannot afford to wait* until something must be done, because the consequences of watershed deterioration are so grave that we cannot sit back any longer. When this stage is reached, it will commonly be too late to do anything of practical significance within the limits of our financial resources. Normally, it must be a case of a stitch in time, or never. The time to deal with a gully, mud-rock flow, or other similar phenomenon, is before, not after, it has come into existence. We must, to the best of our ability, determine and deal with causes, not effects.

Now I grant you that, if we choose to sit back and do nothing, nature will do the repair job for us. Currently, for example, introduced animals are responsible for the greater part of all damage in our watersheds. We have been assured from time to time by students of these animals that the present severe depletion of the plant cover is but a passing phase and that, in the long run, new forms of vegetation resistant to animal use will develop. I admit the accuracy of this conclusion, but I must draw your attention to two major difficulties. The first is that, because we do not yet know what these new forms of vegetation will be, we cannot rest assured that they will be adequate for control of erosion and regulation of the water yield. And the second difficulty resides, of course, in the use of the words “in the long run.” How long is the long run? What happens in the watersheds and to the rivers in the meantime?

I can guess that, in certain cases, the necessary readjustments will proceed rapidly and to a satisfactory conclusion. This is likely to be the case where the potential for erosion is low and local climates favour the vigorous growth of a wide variety of plants; and particularly where, at the same time, one or several environmental factors are adverse to the animals concerned. On the other hand I am certain that, in more numerous instances, a satisfactory conclusion must be indefinitely delayed. Wherever erosion potentials are high, and climatic or soil factors are such that there cannot be
vigorous growth of a wide variety of plants, much ground must remain bare for long periods after the elimination of grazing-susceptible species. The physical forces of erosion will then be in control and there will be no respite until completion of the new erosion cycle. This is likely to be a very lengthy process, demanding a general reduction of angles of slope. It is likely to be a catastrophic process where slopes are at present over steep, greatly exceeding the angles of repose of unprotected soil or rock waste, or where landforms, relics from past climatic eras, are exposed to the full brunt of present climates. I suggest that no one with responsibilities in the sphere of watershed management dare accept assurances that nature will do the job if only we sit back and wait. In a few specific cases, maybe; as a general rule, no! We must put in our stitches in time although future generations may discover that a few of these stitches were not essential.

**Summing-up**

Let me here sum up the things I have said so far: *first*, the sane management of the mountain lands of New Zealand is a matter that should be of immediate and great concern to all New Zealanders; *secondly*, in management of our mountain lands, we face a peculiar and possibly unique combination of circumstances that spell trouble, now and in the future; and *thirdly*, that in mountain-land management prevention is always better than cure. There are two other lessons that I have learnt, but I can dismiss these in a few words without, I hope, straining your patience too far.

**A Complex Study**

The first of these additional lessons concerns the complexity of the field of watershed research. This is brought home to me increasingly the more I study the matter. I do not think that any man ever attains a full grasp of the subject. Necessarily, one man on his own pays close attention to but one set of factors or problems. He is botanist, or forester, or zoologist, or geologist, or pedologist, or hydrologist, or agrostologist, or engineer. The rare student of watershed problems can possibly cope adequately with all aspects of watershed research in one of these fields. The truly exceptional student can possibly handle work in two or three fields simultaneously, effecting a reasonable synthesis of them. Yet the subject demands equal effort in all fields and effective, total, synthesis. Where this cannot be achieved, the probability of misunderstandings and errors in research and management must be multiplied many times. The costs of management will skyrocket. This is only another way of saying that we are going to need the very best men we can find, and that any piecemeal, fragmented, unilateral approach is likely to be self-defeating.
Who are the Right Men?

But not only do we need the best men, technically speaking, that we can find; we need men who are rather peculiar or exceptional in other respects. This is my last lesson. It is going to be extremely difficult to recruit the right men, men who are technically competent in their own particular fields of study and who possess that breadth of training, or breadth of outlook, necessary. It is going to be much more difficult to find men, otherwise fitted for the task, who can face up, physically, to many years of work in the New Zealand mountains.

It is tough work. It is tougher than mountain climbing and tougher than deer stalking. Mountain-lands research work must be carried out in the mountains, throughout the full extent of the mountains, and under all weather conditions – or the work done will be incomplete and possibly misleading. Only fragments of the job can be brought home to well equipped laboratories to be studied in comfort. Only fragments of the job can be tied down to select localities with road access and a roof overhead. By and large, and for many years to come, the research man in the New Zealand mountains must be a mountaineer, an expert in mountain safety and mountain living, a load carrier, a cook, and many other things; and he must be blessed with a wife who is willing and able to look after his family, alone, during his repeated and lengthy absences in the field. The key problem in mountain-lands research in New Zealand, and to my mind the problem that is the root cause of our present miserable lack of progress, is the problem of finding the right men, with the right wives, for the job.

SOME COMPARISONS FROM THE UNITED STATES

There is a big, important, and urgent job to be done, a difficult and complicated job; and it will not be easy to find the men to do it. Can we, perhaps, discover solutions to some of our problems and difficulties by a path less arduous and costly than frontal attack? In many spheres of research, discoveries made and techniques developed in any one country can be applied universally. Can we, therefore, go to the textbooks or to other countries and there find our answers?

Are U.S. Conditions Comparable?

Careful study of the available literature reveals the existence of many apparently parallel situations and sets of problems in other lands, particularly in the United States, whence most of the available literature stems. And many of the solutions that have been worked out would appear to be applicable here. But an even more careful study of the literature creates niggling doubts. Despite appearances, are the situations and the problems they cause, and we face, really comparable? Do we, in fact, speak the same language? Do we, in fact, mean precisely the same thing when we use such simple terms as
“mountain land”, “steep land”, “torrential rainfall”, “over grazing”, “severe erosion”, or “flash flooding”, let alone more erudite terms? When we speak of such things as “small watersheds”, “main-stem rivers”, “upstream and downstream works”, are we referring to things of equal order of magnitude? Is it not possible, or probable, that their attitudes to problems are conditioned by political, sociological, or economic factors of which we are unaware, and that accordingly their solutions cannot be our solutions? My doubts have grown steadily over the past several years. In my reading of the literature, I have increasingly been left with the feeling that, despite apparent coincidences in conditions and problems, there must exist many crucial factors, described but misunderstood, implied but not appreciated, or left undescribed, that completely vitiate comparisons.

The only thing to do was to check these matters on the spot. My opportunity came last year when I attended a Watershed Management Seminar and Study Tour in the United States, under the auspices of the Food and Agricultural Organisation of the United Nations. The time available was very short, but the seminar and study tour was superbly organised and no effort was spared by Federal, State, and private agencies to show us everything that could be seen, and to answer all questions that could be asked, in a few short months. Of particular value were the opportunities for day-to-day discussions with delegates from other countries, some 30 watershed-management specialists from 17 nations. Also of great value was the opportunity given me, prior to the seminar, of spending a month in the mountains with research officers of the Intermountain Forest and Range Experiment Station, Ogden, Utah. Once again, no effort was spared to show me everything that could be seen in the time available and to answer all my questions. To FAO, to the U.S. Forest Service, and to the Director Reed Bailey, and staff of the Intermountain Forest and Range Experiment Station, I am deeply indebted.

**Misinterpretations and Reappraisal**

I do not pretend that I have seen all, or even a large portion of the problem mountain country of the United States, or that I fully appreciate the significance of everything that I was shown; but I do believe that I saw a sufficiently large sample, with sufficient understanding, to justify my drawing certain broad comparisons between conditions there and conditions here. Let me say, at the outset, that though I had read the pertinent American literature as carefully as I could, with the benefit of a previous though casual trip through the Rocky Mountains, I soon discovered that conditions were not as I had imagined them. I had read into the texts situations that were not there. In my preoccupation with New Zealand problems and New Zealand conditions, I had vastly misinterpreted things. To use a current American expression, I found myself compelled towards an agonising reappraisal.
Now I cannot, in the time I have available, drag you through all the steps I took in making this reappraisal, and I cannot describe to you a fraction of the things I saw. All that I can do is to stress the fundamental dissimilarities in conditions between the two countries. I would ask you to remember that, in speaking of the United States, I am speaking of a country so vast that there must be many exceptions to everything I have to say; but I believe that these exceptions, for present purposes, are minor and comparatively unimportant. I shall confine my remarks almost entirely to the States west of the Great Plains. To the east of the Rocky Mountains, though there is much magnificent work being done in watershed research and management, little of it has any immediate bearing on New Zealand mountain-land problems.

The American East. For example, conditions in the Allegheny and Appalachian Mountains and adjacent hill country approximate conditions obtaining in our most stable solid-rock hill lands at altitudes generally below 3000 ft, though our hill-country climates are milder and more equable and our hill-country soils are generally shallower but more stable. The overall trend, throughout the Allegheny and Appalachian Mountains, is towards forest solutions to watershed problems – holding the steep lands in forest or returning them to forest. There is an abundance of agricultural and pastoral land to the west, and questions of water yield and water purity are of paramount importance. But with respect to our hill lands, our inclination is everywhere towards grassland solutions, an inclination dictated by our shortage of agricultural and pastoral land and permissible because our climate and the techniques we have developed allow us to grow good grass. Questions of water yield and water purity are not of such overwhelming importance. There will be many things that we shall be able to learn from research under way in these mountain lands of the American east, particularly about management of hill land set apart as a collecting ground for industrial and domestic water; but there will be little that will be directly applicable in management of our high mountain lands.

The American South and Middle West. Moving now, very rapidly, across the southern piedmont, the Mississippi valley, and the Great Plains States, I pause only to note that the immense soil-conservation and watershed-control problems that exist in these States have no close parallel in New Zealand. By and large, in all these States, soils are very much deeper and more fertile than any of our lowland soils ever were. At the same time, erosion hazards are infinitely greater and it is much more difficult to grow good grass. For climatic and traditional reasons, and frequently because of early mistakes in fixing the size of individual farm units, cash and fodder cropping have been universal. We might have been faced with problems of the same
type on the rolling pumice lands of the Waikato valley had we been forced to cash crop these lands intensively without being able to blanket them under a strong grass sward. But even then our problems would not have been of the same order, for it must be remembered that the States concerned have an area 20–30 times that of the whole of New Zealand, largely draining into the one river. These States are the homelands of many practices with which we are all familiar—contour cultivation, strip cropping, terracing, stubble mulching, and so on; but despite all that has been accomplished there is a long way to go before the soil is safeguarded as adequately as New Zealand lowland soil. I may be permitted to wonder whether, in their enthusiasm, some New Zealand soil conservationists have not been inclined to go too far in pressing on New Zealand farmers the adoption of the land-management techniques mentioned—when the grass we can grow does the job so much better.

Water is Scarce. Very few home-hugging New Zealanders can have any real appreciation of the immensity of the soil-conservation and rivers-control task that the Americans have been called upon to face, almost throughout the Southern, central and Midwestern States: a consequence of the types of agriculture that have been forced upon them by their climate, and of the highly erodible nature of their soils. Certainly very few New Zealanders can have any real appreciation of the immensity of the water-supply problem that Americans are called upon to face, almost throughout the western half of the United States. Throughout this immense area, from and including much of the Great Plains States right through to the Pacific coast, with exception only of the coastal mountains from San Francisco to the Canadian border, water shortage is the one great problem. The valleys and the plains are arid, and hot in summer, beyond anything we know in New Zealand. The entire future of these western States depends upon the conservation and regulation of the water that falls as rain or snow on the high mountains and plateaus. This is the one great fact that underlies all American thinking on the subject of watershed management in the west, determining the direction of watershed research.

The problem of water for the west is one of the greatest internal problems that the American nation is called upon to solve. It is a particularly difficult problem because it must be solved within the framework of a veritable jungle of Federal, State, and local law, with confusion compounded by the existence of a host of rights, privileges, and traditional water usages. I mention these things because they, also, have a strong bearing on the direction of research. How strong, I cannot tell you. I only know that these difficulties exist and that we must realise they exist if we are to understand the situation in the Western States. It would take a far better brain than mine to ferret out all the facts, evaluating their full significance. I must admit, however, to a sneaking fear that the lesson the Americans may be
teaching the world is that it will be impossible to maintain a modern industrial civilisation in an arid land (they would call it semi-arid) on a foundation of a completely laissez-faire economy.

But I digress: to return to the watersheds. The first and foremost call is for water—more water and still more water for the great cities and industrial centres that have sprung up in the deserts (or semi-deserts), water for vast irrigation projects, and water to replenish shrunken and shrinking ground-water reservoirs. How should the mountain lands be managed to produce the maximum yield of water at the right season of the year? Will more water be obtained if the mountain forests are replaced by grassland, or by other planned manipulation of the vegetation? What innovations can be introduced into the logging of the mountain forests to ensure maximum accumulation of winter snow and to delay the melting of this snow? How best to control evapotranspiration losses or to eliminate losses due to water-wasting riparian plants? How best to determine the volumes of water that will be available next summer? How best to use the water at the end point? These are the crucial questions. All else, in truth, is of secondary importance, though other matters may appear to take first place on account of their local or traditional importance or for political reasons.

Erosion control and flood prevention. These matters are of great local significance, particularly where towns and cities have been allowed to grow on risky ground—on stream fans where water was readily available or at the mouths of canyons (we would call them gorges or valleys) where down-valley winds give some small relief from summer heat. Costly works of considerable technical excellence have been undertaken in many such instances—contour terracing of mountain grasslands damaged by overgrazing, construction of dams to reduce stream gradients and flood velocities, construction of debris-retention basins, and so on. But we would deal with these problems principally by prohibiting building in such places, either directly or by imposition of steep differential rating according to the degree of flood risk. On a wider front, there is great concern with items that would give us little cause for worry. For example, where logging roads must be constructed through steep mountain country in northern Idaho, there is the danger that considerable quantities of sand, derived from the weathering of weak granites, will be discharged into headwater tributaries of the Columbia River. Sand in this quantity, reaching our short, swift rivers, would be swept to the sea in the first flood. In the case of the Columbia River, it must lodge somewhere en route. It is a matter of scale. All our rivers are roughly the equivalent of their headwater tributaries; we have no equivalent to their main-stem rivers. A minor increase in debris load or a minor acceleration of storm-water discharge is frequently of no significance in the headwater tributary concerned; but combine many of
these into one great main-stem river and there is an immediate and serious problem to be faced.

**Slight v. Catastrophic Erosion**

On the whole, therefore, it would be correct to say that the Americans in the west are concerned with the cumulative consequences of slight to moderate accelerated erosion over vast territories and immense river catchments. We are concerned with severe to catastrophic erosion affecting comparatively small river catchments. Our problems are acute but not cumulative. Their problems, considered one at a time, are comparatively modest but cumulative.

**Accelerated erosion**, as we know it in New Zealand mountain country, is unknown, or almost unknown in the mountains of the American west. Their mountains display fantastic erosion forms, particularly in true desert areas and on the lowermost slopes of the mountains below the limits of alpine rainfall and snowfall; but these forms are normal to any arid and mountainous land. Where our landscapes tend in the same direction, under humid to super-humid climates, this is clear evidence of gross land mismanagement. I think that I should not be seriously in error in saying that they have no considerable extent of mountain country where the mountains are as young and steep, and are composed of such rotten rock, as our main-divide greywacke ranges. If they have, I did not see them, was not told about them, and have found no reference to them in the literature. I was shown areas where the rock was said to be weak but it was not weak or rotten as we use these terms. By our standards, the rocks of which their mountains are composed are solid and erosion resistant – on a par with the rocks we find in Fiordland or in the mountains of north-west Nelson, areas which give us no great cause for concern. But if I am wrong in saying this, I am not wrong in saying that they have no young, steep, rotten-rock mountains exposed to torrential rainfall, using this term in its New Zealand sense. It is possible that there are mountains in New Zealand where the total annual precipitation at high elevations is as low as 40 in., though I doubt this very much. I think that when we get around to measuring it, we will find that total precipitation at high elevations, even in our driest mountain country, amounts to 60–80 in. per annum or more. This is tantamount to saying that annual precipitation in our lowest-rainfall mountain country falls little short of total precipitation on their wettest mountains. There are no reliable figures for total annual precipitation on our wettest mountains, but this is certainly over 200 in., probably over 300 in., and possibly over 400 in. Let me express these facts another way. Total annual precipitation on the mountain ranges of the American west rarely exceeds 40 in. In many places we can get this much in one week. In a few places we can get nearly this much in one day.
Even this, however, is not the full story. You will note that I have consistently used the term “total precipitation”, not the term “total rainfall”. In fact, most of the water that falls on their mountains falls as snow in winter. With us, on the other hand, at elevations below the permanent snow line, most of the water falls as rain. This is a most important distinction. Snow, when it falls, does not dislodge the soil. It protects the soil. There is a short-term risk if and when the snow melts too rapidly in spring, but this is not usual. Normally, melting proceeds slowly enough for the melt water to be discharged to the streams through, not over, the soil. In effect, the mountain soils of the Western States are completely shielded against erosion for five to seven months of the year. For the remaining months erosion hazards, by our standards, are slight because it seldom rains, though there is risk of damage from short sharp thunder showers of high intensity if these fall on bare ground. Heavy accent in research falls on protection of the soil from the impact of these brief-duration high-intensity showers and on the maintenance of the capacity of the soil to absorb them. But this problem, though aggravated by the difficulty of maintaining an adequate plant cover on soils that are seasonally moisture deficient, appears to me to be a minor one in comparison with our problem of holding shallow, excessively weak-structured soils in place on very steep slopes under our rainfall conditions.

The heavy winter snowpack does much more than protect the soil from raindrop impact. It protects the soil from frost lift and the rock from frost shatter. It protects the vegetation, under the snow, from the extremes of winter climate. It is the climate at ground level that matters most, not the climate at the snowpack surface. I have no hesitation whatsoever in saying that New Zealand mountain-land climates are more severe on the soil, on the rock, and on the vegetation than are the mountain-land climates of the Western States, despite the fact that air temperatures in the States fall far below any experienced here. Conditions common over much of our mountain country, in respect of the action of freeze and thaw, are found in their mountains only on warm-aspect slopes below the line of heavy winter-snow accumulation, i.e. at altitudes where total annual precipitation rarely exceeds 10–20 in., so that the products of soil lift and frost shatter are not immediately transported to the rivers and streams by running water.

Other Differences

But I must cut myself short. I could go on and on. There are many other outstanding points of difference. Their high-mountain soils are frequently deep and fertile, and commonly neutral or alkaline, though strongly moisture deficient in late summer and autumn. Our mountain-land soils are shallow, acid, and infertile though
almost always abundantly wet. Topographic differences are marked. Our mountains, at high altitudes, are generally much steeper than theirs. We have no counterpart to their high-altitude plateau lands and only on the schist ranges of Otago and Southland do we find mountain summits as gentle as many throughout the Rockies, at double or more than double the altitude. In sum their most rugged high-altitude lands, though cut by deep canyons and bounded by steep escarpments, would not exceed our average mountain lands in difficulty. Wind, as an agent of erosion and as it affects the vegetation, I have not mentioned. There can be no question that wind is a factor of greater significance in the New Zealand mountains than ever it is in the Western States. The gale-force winds that blow, week in, week out, through much of our mountain country would transport their mountain soils to the plains in very short order.

The net result of all these things is that their mountain streams—considering streams of equal catchment area—maintain much smaller average flows, probably achieve much lower peak flows, flood more rarely, and carry negligible loads of rock waste in comparison with any average New Zealand mountain stream. These obvious distinctions in stream-flow characteristics sum up the distinctions in the physical environment better than anything else could do. A further summary is contained in the fact that vegetation zones are largely reversed between the two countries. Our forests and good grasslands lie in the valleys and on the lowermost mountain slopes. Theirs lie towards the crests of the mountains and on the high plateaus. Our high-altitude vegetation types are our weakest in the face of animal grazing and browsing, and give place at progressively higher elevations to open plant communities and alpine cold desert. Their weakest vegetation types in the face of animal pressure are those that occur below the winter snow line, giving place with decreasing altitude to the open plant communities of hot dry desert. Alpine cold desert occurs on their mountains only at altitudes exceeding, by many thousands of feet, our summer snow line.

Grazing and Browsing Animals

This brings me to the last aspect of the American scene that I have time to discuss. I have already stated that the greater part of all damage apparent in our watersheds today is a consequence of the introduction of grazing and browsing animals. I have also mentioned the assurances we have been given, by students of these animals, that we have no real cause for worry because, in time, new forms of animal-resistant vegetation will develop and natural controls over animal populations will come into operation. Snags in the path of acceptance of the first assurance, that concerning the evolution of new types of vegetation, I have already dealt with.

287
Is there anything wrong with the second assurance, the development of natural controls?

The entire notion appears to be based upon analogy with conditions obtaining in the Western States where grazing and browsing animals have always been present. Let me say, without hesitation, that it has no foundation in fact. There exist natural controls over populations of game animals in the Western States that cannot operate to any substantial degree in New Zealand. I do not refer to control by predators, because there still appears to be room for argument concerning the effectiveness of predation in controlling prey populations. I refer to the simple and effective control that is exercised by climate. In summer the game animals of the Western States have free access to immense areas of high-altitude forest and grassland. The summer climate is mild and there is an abundance of nutritious and highly palatable food. But in winter, as the snowpack accumulates, the animals are forced downwards into the open woodlands, scrub forests, and grasslands of the desert fringe where food reserves are short and severe cold is experienced. Therefore, whenever populations build up on the summer range, there is inevitable overpopulation of the winter range. Herd strengths are drastically cut back by malnutrition coupled with exposure. Serious trouble is experienced on the summer range only where foolish attempts are made to curtail winter losses by hand feeding, or where there is some restriction on the movement of the herds (e.g. through pre-emption of much of the range by domestic animals).

In contrast, our winter range is extensive and contains an abundance of palatable and nutritious food. Climatic conditions are not severe, not infrequently being less harsh than summer conditions on the summer range. It is only where there has been prolonged and gross overpopulation of the entire range that there is risk of exhaustion of winter food reserves and consequent reduction in herd strengths through malnutrition. By the time this stage has been reached our limited and hazardous summer range has normally been hit to the point of no return. By the time severe depletion of winter range is evident, acceleration of erosion on the summer range is likely to be so far advanced that there is no practicable cure. Control of the watersheds has been lost.

It would be very easy to select exceptional cases both from the Western States and from New Zealand, matching one against the other to "prove" that conditions in the two countries are comparable. But, in by far the greater part of the lands concerned, it is the winter range that is the weak point in the States, the summer range that is the weak point with us. The struggle, in the Western States, is largely to maintain the carrying capacity of the summer range so that sufficient game animals will be available to meet the
needs of hunters. Our struggle is primarily to maintain the densest possible plant cover on our erosion-subject summer-range lands—a very difficult thing to do where there are no natural controls in operation, and sometimes an impossible thing to do in the presence of any grazing and browsing animals at all. The two situations are in no degree comparable; I pause to note just one or two other essential distinctions.

Soil Compaction

I have remarked that, in the States, heavy accent falls on maintenance of the capacity of the soil to absorb brief-duration high-intensity showers. Loss of this capacity is largely a matter of soil compaction through trampling by animals, particularly of moist or wet soils. Our mountain-land soils are almost always wet. Their soils are dry for much of the year. Our soils, once compacted, tend to remain so. Their soils are restored to a loose and porous condition by intense rodent and other soil-faunal activity. If they are concerned with soil compaction, we should be deeply worried. It is my conviction that, on this score alone, we dare not countenance the presence of hoofed animals on our steep high-rainfall mountain country. Our wet, weak-structured, mountain-land soils undergo compaction when trampled and this cannot but lead to loss of capacity to absorb rainfall. Under our rainfall conditions this, in turn, must lead to a sharp rise in surface flow, a rise in flood peaks, and initiation of accelerated erosion.

Hunting. Finally, I must mention the question of manpower and hunting pressure. There should be no need to elaborate upon the vast differences that exist between the United States and New Zealand. The Americans could decimate their game-animal herds at will, for there is an immense and unsatisfied demand to hunt. By declaration of open seasons, many herds could be virtually wiped out. At a pinch shooting pressure exerted over the winter range would soon complete the story—not that these things would be politically possible; they would be politically impossible, for the animals concerned are the sacred beasts of American tradition just as much as sheep are the sacred beasts here. But the technical possibility does exist. Stringent hunting laws are required to prevent it.

We, on the other hand, cannot exert the required pressure though elimination of the animals meets scant political obstruction. It is not only that we have insufficient manpower to do the job; it is also largely on account of the topographic and climatic difficulty of the country. Even could we import American hunters in unending streams, I doubt that we would do more than wipe out the herds along the foothills and in the most readily accessible valleys. The hard-core problem would remain—the control of deer, chamois, thar, and other animals in the difficult country, remote from road
access, that lies behind the river gorges, in other words the country where hunting soon ceases to be fun and becomes hard, unremitting, and dangerous labour. Where the deployment of many men is required, it is not so much what the exceptional man is capable of doing that counts. It is what the average man is capable of doing or is prepared to do that matters. After seeing the conditions under which hunters operate in the States, and after discussing our conditions with many American hunters and game-management men, I am certain that the average American hunter would not be prepared, physically or in any other way, to hunt our hard-core problem lands. This is no slight on the Americans. Very few New Zealanders are capable of doing it.

THE SITUATION IN OTHER LANDS: CONCLUSIONS

I am very conscious of the fact that, though I have been long winded, I have given you but the sketchiest outline of watershed conditions and watershed problems in the United States. I have, in fact, attempted only to highlight a few of the fundamental differences that exist between conditions there and conditions here. The one point that I have tried to make clear is that, despite superficial similarities, the problems they face are not the problems we face. When we discuss the broad basic principles of watershed management we talk the same language; but when we come to consider particular cases, or seek solutions to particular problems, then we have little in common. We shall be able to adopt, or adapt, some of the research techniques they have developed, particularly in the sphere of fundamental research, though even in this sphere we must be very careful lest superficial resemblances conceal important differences, leading us far astray. In the spheres of applied research and practical land management, I am certain that we shall very rarely be called upon to deal with identical problems demanding identical solutions. The textbooks may make it appear otherwise, but texts can be misread and misinterpreted. Before we employ American techniques or seek to apply American solutions, we must be very sure that our problems are the same.

I do not think that we shall find solutions to our most urgent problems in the United States. Can we discover them in other mountainous lands? I am afraid that the answer must again be no! As I have already mentioned, I had many opportunities for discussions with watershed-management specialists from other countries, some of whom had a good working knowledge of watershed problems in many other lands also. We would start by discussing some particular American problem, relating this to the problems of our homelands. Did any one of us have this same problem? If so, could we approach it or solve it in the American manner, having regard to our own technical, financial, or manpower resources and our own
political system? If we did not face the same problem, despite possible superficial resemblances, wherein did the difference lie? Did we, perhaps share difficulties that the Americans did not face?

In other words, by give and take, it was possible to discover much about the problems existing in these other lands. I failed to discover, however, any country with quite the same, or nearly the same, combination of problems that confront us. Our rainfall can be matched, our topography can be matched, our rotten rock and weak mountain soils can be matched, our torrential gravel-laden rivers can be matched, our tectonically unstable landforms can be matched; but not all these things in combination. In particular, our history of animal introduction into a land previously devoid of grazing and browsing mammals could not be matched other than in the case of a few small islands. These conclusions are supported by everything that I have read and by all advice given me by overseas visitors to New Zealand.

I am very much afraid that we stand alone with our problems. Our set of problems is something unique, or if not unique then it exists elsewhere only in some more backward land, unrecognised and unstudied. And this set of problems we must solve more or less on our own, without access to the vast manpower reserves of more densely populated countries and without access to the financial and technical resources of greater nations.

By this I do not mean that we cannot go overseas for help and advice. We must go overseas (and I mean this in its literal not figurative sense) to collect every scrap of information that we can. We must go overseas for new plant species to bolster those of our vegetation types that are failing under pressure from introduced animals. We can go overseas, particularly to the older mountain lands of Europe, to learn how to repair certain types of watershed damage and how to correct and train mountain torrents. The Swiss, the French, the Italians, the Austrians, and the Greeks can teach us many tricks. Greek foresters, for example, are tackling with vigour problems of the sort that will face New Zealand foresters in the future, if we do not take preventive action in time. We must not, however, wait until we are in their situation, with torrent-correction works consuming almost the full energy of the Forest Service. Japanese foresters should be able to give us many lessons - the management of high-rainfall, mountainous, forested land was a matter of great concern in Japan before ever New Zealand was discovered, though we will never have at our disposal a manpower resource equal to theirs.

It is important that we seek every opportunity that offers to study overseas, taking full advantage of the experience of other people and applying to our problems such of their techniques as are pertinent. We shall always have enough, and more than enough,
work to do here in the study and solution of problems that are peculiar to New Zealand. Moreover, before ever we do go overseas, we must make sure that we understand the real nature of our problems. It will almost always be necessary to adapt and modify overseas techniques to fit our local circumstances, and this will not be possible unless we are thoroughly cognisant of all variations in conditions, physical, biological, sociological, and political, on both sides of the fence.

Finally, and this time I mean finally, we can and probably must go back to the United States to learn how to gain the support of the man in the street. The know-how in watershed management must be provided by specialists, but action must stem from the people themselves. Without their informed interest and determination to see something done, the specialist can achieve very little. This is the one great lesson that the Americans can teach us – the importance of the informed and determined interest of the average man; and they can teach us that time spent on public education, time spent in the development of public leadership, and time spent in the presentation of research results in a form that the average man can read with understanding is not time misspent. Call these things propaganda if you will; they are nevertheless of immense importance to us.

I have no doubt that, in relation to our resources, we have as tough a set of problems to face in management of our high-mountain watersheds as any country. I have no doubt that we must discover most of our answers for ourselves and by our own efforts. There can be no doubt at all that it is going to be a tough job and a very long job, and that it is going to be very difficult to find the men to do it. It is not going to be sufficient to leave the job to a few enthusiasts or to enlist the support only of other scientists or even of departments and agencies of central and local government. The support of the country as a whole is essential, particularly the support of those who have it in their power to create conditions that will attract the right men, and sufficient men, to the field.