SOIL CONSERVATION PRACTICES IN FRANCE

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Summary

In this, the first of two articles, the experience of French foresters working in the counter-erosion field is reviewed. Following brief historical and geographical accounts of the incidence of accelerated erosion in France, the methods employed in correction of torrents and in stabilisation of eroding catchments are described. The approach is two-fold. First, the torrents are brought under control by means of dams and other structures built in the torrent bed and in the beds of feeder torrents. And secondly, the engineering works are themselves protected by restoration of an effective plant cover, forest or grassland, in the torrent basin. The two procedures are completely complementary.

In a subsequent article the question of the possible application of French techniques in New Zealand will be discussed.

INTRODUCTION

From the beginning of historical time phenomena of accelerated erosion have been in evidence throughout the world. The Mediterranean basin is probably one of the best known examples. Once largely clothed by forests of cedar, pine, and cypress, the basin now contains vast expanses of desert terrain following centuries of deforestation, pastoral abuse, and fire.

More highly developed countries of the recent era, such as France, Germany, and Italy, have at some stage in their development exhibited the same features to a lesser degree. In all cases the root of the evil is to be found in soil degradation, following closer utilisation of marginal and basically unstable land to supply the needs of an increasing population.

New Zealand, then, is not alone in exhibiting these unwelcome landscape features; prior to 1840 a great part of the alpine area of France presented much the same picture as does New Zealand's high country today, only the scale was less spectacular in France. Evidence of sheet and gully erosion, flash flooding, and the building up of stream beds with consequent damage to farmlands and communications, so obvious in New Zealand today, was to be found throughout the French Alps in the mid-nineteenth century. In both countries the cause was the same—utilisation of land in a precarious state of balance without proper knowledge of the conditions necessary for its protection.

In 1841 the first cry of alarm was raised in France, not by a forester or agricultural expert, but by a Public Works engineer, by name Surell, stationed at Gap in the southern region of the French Alps. Surell was naturally more closely affected by the question of erosion than most people in this region, for his was the task of keeping communication routes open with other parts of the Alps. This was no easy task in the face of accelerated erosion, and the biggest problem was that of maintaining existing bridgeworks. Surell was probably the first man to realise the value of tree-planting, wattling, etc., to maintain stable conditions in river catchments.

In 1860 legislation was introduced to assist the Forest Service which by this time had taken over the work started by Surell. This legislation was a step in the right direction, for it gave the Forest Service the right to intervene in areas directly affected by erosion, and carry out protective works. It did not, however, convey the right to expropriate land in danger zones for protection purposes, and it was only the Law of 1882, reinforced by that of 1913, which gave that right. These laws made the establishment of protection zones obligatory where such establishment was deemed to be in the public interest.

By the time the Law of 1882 had been passed, the classical methods of torrent correction using dams and complementary works had been evolved by Demontzey, a forester, and a separate section of the Forest Service had been formed to devote its time essentially to soil conservation problems. Demontzey was, then, the father of conservation work in Europe; other countries were quick to follow the lead given by France. By 1885 the teachings of Demontzey had spread to Austria, Germany, Italy, and Switzerland, and Europe had taken up the struggle against erosion.

EROSION REGIONS IN FRANCE

France has two major mountain systems—that of the Alps which runs in a north/south direction along the Italian border, and that of the Pyrenees which forms the Franco-Spanish frontier along the greater part of its length. The former chain extends from the Lake of Geneva in the north to Nice in the South, and is by far the more important of the two.

French Alps

This chain is merely a continuation of the chain of the European Alps which form the well-known Tyrol of Austria, and the Swiss Alps. Through Austria and Switzerland the major chain is oriented east/west, but at the Lake of Geneva it swings away to the south forming the French Alps. These latter, covering as they do some 250 miles in a north/south direction, are subjected to varying climatic influences, especially where they approach the Mediterranean. On the basis of this climatic variation they are divided for practical purposes into the northern, or "Green Alps", and the southern, or "Dry Alps". Along its length the major chain is fringed by parallel chains of lesser importance which nevertheless reach quite important altitudes.

1. *Northern Alps*

A high rainfall area which holds less interest for the forester than formerly. Due to heavy Pleistocene glaciation relief is more regular than in southern regions. The major chain is thin, and composed almost entirely of primary granites, and gneiss. Fringing chains of secondary sediments are of little importance. Due to these favourable conditions, the maintenance of a stable vegetative cover presents few difficulties; the greatest problem facing the forester is that of protection against winter avalanches.

2. *Southern Alps*

The erosion area, "par excellence", in France. Most of the region has escaped heavy glaciation and the rounded glacial landforms so prominent in the north are almost completely lacking. The Mediterranean climate, with its long, dry summers, and its torrential spring and autumn rains, does not allow the development of an important, stable vegetation, and the flora is characterised by vernal species which are of little value in conservation work. Further, the dominance of soft secondary sediments in the geological make-up is extremely favourable to torrent development. Most conservation work in France is carried out in this area.

Pyrenees

Two-thirds of this east/west chain lie in Spanish territory; only the steep, north-facing slopes are of interest to the French forester. Throughout the length of the chain terrain is more solid than it is in the Alps, and only at the eastern end, where the Mediterranean climate is encountered, is there any dangerous accelerated erosion. At this end, also, relief is much more broken; altitudes of 10,000 feet are encountered at distances of 30 miles from the coast.

Each of the three above-named regions is served by a special branch of the Forest Service. This is the R.T.M. (Restoration of Terrain in the Mountains), and each region has three work groups. These groups comprise a forester, with from five to six assistants. These assistants have passed through the Ranger School at Les Barres, where, besides general forestry training, they have specialised in Soil Conservation work. There are thus nine professional officers and some fifty assistants engaged actively in conservation work in France, besides a small staff which directs operations and initiates research from the Forest Service Research Station at Nancy.

BASIS OF CONSERVATION MEASURES

It has been seen that early corrective measures were those conceived by Surell and Demontzey. Present day methods differ little from the original concept. Basically, the work falls into two classes. Primary works are directed toward the establishment of the torrent in a fixed course with a stepped longitudinal profile using dykes and dams. Secondary works have for their object the fixation of banks and slopes by the planting of forest trees, wattling, sodding, etc. Although termed secondary, these works are completely complementary to the first described. There would be little to gain in the establishment of a series of dams if these were not protected from the mass of detritus descending from above.

PRIMARY WORK

Torrent Characteristics and Classification

Although the Oxford Dictionary describes a torrent as "a rushing stream of water", the term is generally used in conservation work to describe a steeply sloping stream of limited size which feeds a more sedate valley-bottom river. The average slope of such a stream exceeds 6 per cent, although slope varies along the length of the stream. In the headwaters, or basin, slopes are not excessively steep, and it is here that small streams join to form the main channel which is characterised by very steep slopes. A zone of reduced slope is found where the torrent joins the valley-bottom river, the outwash fan. For each of these sections of the torrent there is a corresponding method of treatment; these will be elaborated later.

Torrents fall into two classes, depending on the origin of the material they transport.

The most common type, and that which lends itself most readily to correction, is the "eroding torrent". Here the detritus is the result of the eroding action of the water on banks and slopes.

A much more difficult proposition is the "boulder-moving torrent". In this case detritus is fed into the stream by falls of rock and earth from escarpments, and is in no way due to the eroding power of the waters of the stream. In this type of torrent the source of detritus supply is often inaccessible and such torrents are often, for technical reasons, not able to be corrected. Only the course of the floodwaters in the lower reaches can be diverted by the action of man, although this is often sufficient for practical purposes.

Torrential rivers, as the name implies, have some characteristics of both river and torrent. These are the streams which collect the water from torrents and carry it out to lower levels where it is in turn collected and carried to the sea. Due to their volume such streams are rarely corrected, although they are the cause of much damage to lines of communication and farm-lands in the major alpine valleys. The lower areas can only be protected by complete correction of the feeder torrents. Danger areas in torrential rivers are protected by groynes, breastworks, and plantations of willow, and poplar.

Establishment of the Stepped Profile . . . Dams

All streams which have not reached their local base-level have the power to erode their beds. The ability to erode is a function of the slope of the bed and the nature of the surrounding terrain. As torrents have characteristically steep profiles, their "coefficient of torrentiality" is always high.

Demontzey had the idea that the normal steep profile could be replaced by a stepped one of reduced slope by the use of a series of dams along the stream bed. Detritus carried in time of flood would find its passage barred by the transverse dam and would settle to the bottom, thus building up a level platform behind each dam. By the use of a series of dams, Demontzey envisaged the path of a torrent as a sort of gigantic stairway in which the kinetic energy of the water was dissipated at each dam. In practice his ideas proved to be well-founded; there has been no significant change in the methods used to the present day.

In a typical Correction Project, once the preliminary survey of the catchment has been carried out, the location of the principal dam is sought. This dam, the key-dam, is situated in the bed as close as possible to the point where the stream forms its fan. It must however be so situated that the stream banks are stable on each side so that the construction is assured a long life. This key-dam is one of the most important works in the project and every care must be taken in its construction, for loss of this dam at a later stage would spell disaster to the whole scheme. To guard against destruction a small "counter-dam", joined to the main structure by a concrete apron, is erected downstream. This dam effectively breaks the force of water falling over the main structure and prevents undermining of the foundations, a common cause of destruction.

The thickness of the key-dam is calculated so that it may resist the force of floodwaters before filling and, once the filling stage is passed, the weight of accumulated material behind it. This entails the construction of some very big dams in streams which are known to carry high floods. An important point in the construction of these dams is the thickness of the parapet over which the floodwaters must pass. If this is not substantial enough, or if care has not been exercised in its construction, large blocks carried in time of flood are liable to cause cracking which results in the eventual destruction of the dam. These parapets were originally built in hard stone blocks, but present day practice tends toward the use of a variety of materials including reinforced concrete and metal plates which have a greater resistance to wear.

Once the key-dam has been established smaller dams are erected upstream from it at suitably stable points. Apart from the fact that there is rarely a counter-dam, these are similar in other respects to the key structure. In some cases where the terrain is unstable, the concrete apron is to be found. The height to which these dams are built above the stream bed is not arbitrarily chosen. It depends on the number of suitable dam sites which can be found, and on the nature of the transported material in the stream. In theory there should be a level filling between successive dams, but it is seldom possible to achieve this objective in practice. Instead, the slope is calculated between dams at which most of the finer elements in the detritus are not transported during normal stream-flow. It is obvious that under the same conditions heavier material will also be stable. Take as an example a torrent which normally carries a high proportion of fine elements in suspension; in this case there would be need for a greater number of steps than would be the case if the stream carried predominantly coarse material, for the slope of each step must be less. If the number of dam sites is limited, then dams must be correspondingly higher in the case of a torrent carrying fine elements. The calculation of this "compensation slope", as it is called, is one of the most difficult in correction works, and is dependent on a long experience in correction work and a complete knowledge of the geology of the area.

On the completion of this series of dams, transport of detritus in the stream bed is effectively reduced; it is at this stage that secondary works to be described later are undertaken, so that small ravines and slopes are no longer in a position to supply material to the torrent. There is, however, one other important task to be undertaken in the stream bed itself.

Once the dams have been filled, and transport has been reduced, the clearer water resulting from these operations has a much greater power to erode, and the banks along the main channel are in constant need of protection. Were it not for this protection, dams would be easily turned at the banks during flooding. The banks are protected at danger areas by the use of dykes and groynes, and a variety of methods and materials are used. Dykes were once universally constructed in dry stone masonry, or wood, depending on the material to hand, but now the tendency is towards the use of concrete, or the familiar netting cage filled with stones. In many cases the lives of these stone structures has been lengthened by the introduction of concrete, under pressure, into the mass.

If the methods of correction have changed little since the days of Demontzey, the technique of construction most certainly has. This is due, not only to the appearance on the market of special cements, and to use of advanced concreting techniques, but also to the loss of labour, both skilled and unskilled, in alpine regions.

Dams were once curved in plan so that they were more able to resist the thrust of the filling behind. Now they are universally straight, as it was found that the thrust from the banks was in many cases greater than that of the filling, and many curved dams were destroyed in consequence. In the same way, the basin behind the dam was once so shaped that most of the water was carried over the central portion of the dam. So great was the wear on the parapet, however, that a trapezoidal shape was adopted to spread the water as much as possible in its passage over the dam.

It is in the field of building materials that the greatest changes have been brought about. At the beginning of the century most dams were built using stonework and mortar, or a mixture of this with dry stone masonry. Owing to the materials used, such dams rarely had a long life, and replacement costs became higher as suitable labour became scarce. At the present time most dams have a concrete core with a veneer of stonework, the whole resting on a solid foundation of reinforced concrete. In some cases stonework is still used, but mortar has been replaced by cement. More important structures are often in vibrated or reinforced concrete. These works now call for less skilled labour than formerly, which is as well since there are very few skilled tradesmen left in the alpine regions of France.

SECONDARY WORK

Work described under the previous heading had as its object the establishment of the torrent in a more or less permanent bed with its slope considerably reduced by the construction of dams along its length. This work would have little lasting value if the upper slopes were still capable of supplying detritus to the stream, so that complementary works are essential to stabilize the slopes.

It is at this stage that a complete knowledge of the botany, geology, and climate of the area is essential, for most of the work consists of the introduction of plants, or the increase of existing vegetation. But before this work is undertaken there is one other task which falls to the "engineer-forester", rather than to the forester. This is the correction of small tributary ravines in the upper basin and along the walls of the main channel.

Correction of Secondary Ravines

Methods used in the correction of small ravines are similar to those used in the major torrent—only the scale of the works differs.

In place of the series of dams, a succession of small falls, or steps, is substituted to reduce the slope. In the bed of the ravine, these steps, usually in dry masonry, are constructed at intervals which depend on the original slope. These steps are only five to six feet wide in most cases—not fifty to sixty as is frequently the case in the major torrent. Their height is seldom more than two feet, so little filling takes place behind each step. Due to the great number which much be employed in unfavourable circumstances the cost of such works is often high, and if there is little danger of serious flooding, they are often replaced by less costly structures.

In forested zones, steps are replaced by so-called "living dams". These dams are made of wood, and span the stream bed except for a central portion which allows the passage of water. The construction of these units is relatively simple. Two lines of stakes, roughly six inches apart, are driven into the ground across the bed of the ravine. Into the space between the lines of stakes are slipped brushwood and small poles. This forms a very effective barrier which will last as long as the stone steps provided there is no very heavy flooding. Willow cuttings are often established behind these dams. Timbers most commonly used in the construction of these works are larch, spruce, Austrian pine, and *Pinus cembra*. These species, with the exception of Austrian pine, introduced on a large scale about 1870, form the natural forest stands in the Alps.

In deforested zones, such as the dry southern Alps, an interesting type of construction has been designed and brought into use recently. This is known as the "Dugelay Step," after its inventor, and is now widely used. It consists of two reinforced concrete posts with a groove running down their length on one side. These posts are embedded in the ground about six feet apart and thin "planks" of reinforced concrete are slipped into the grooves. As the height of the filling rises, more planks can be added without difficulty. These steps give the utmost satisfaction except in areas where there is much danger from rolling stones. The main advantage of this type of construction is that the pre-fabricated elements are readily transportable.

More and more use is now being made of netting cages filled with stones in areas where transport of other materials is difficult. The important points in the construction of these works are the proper filling of the cages and a solid foundation for the structure. Filling of the cages is perhaps a misleading term, for in practice a dry stone wall is built up inside the cage using as many flat stones as possible. When the framework is closed, and correctly stayed, the structure is extremely solid if the foundations are sufficiently deep. It is not uncommon to see trenches three feet deep as the starting point for these structures.

Following the completion of these steps, by whatever method, correction of the ravines is completed by wattling of the bed and fixation of the banks. In forested zones it is common to see heavy branches, and even small trees from early thinnings, used for this purpose. The branches are laid flat on the ground between the steps and are fixed to the soil using lianes, or wire, and wooden stakes. Where conifers are used for this purpose several layers are put down and, if conditions are favourable, some of these oversize cuttings become established in the bed. In deforested zones brushwood is laid down in a lattice and willow cuttings are established amongst the brush. This lattice of brush, or branches, besides breaking the force of the floodwater, forms an effective silt-trap permitting the later establishment of vegetation under more favourable conditions.

Stream banks are usually fixed simply by use of willow cuttings, but where the banks are excessively steep, or unstable, a certain amount of wattling may be necessary.

INTRODUCTION OF VEGETATION

A. *Plantations Below the Tree-Line*

A necessary condition for the direct establishment of forest species on denuded slopes is that the ground is stable. In eroded catchments this is seldom the case, especially at higher altitudes, and thus some modification of normal establishment procedure is called for. French foresters suffered many serious setbacks in this type of work; and it was only at the end of a long series of experiments of a trial and error nature that successful techniques were devised.

Where slopes are steep and the soil is unstable, it is usual to proceed in three stages in the establishment of forest species. In the first stage, any species, not necessarily tree species, capable of colonizing the site are chosen with preference given to nitrogen fixing species. Thus one is likely to encounter many members of the Leguminosae, Papilionaceae, and Caryophyllaceae families, together with such tuft-forming grasses as *Calamagrostis argentea* and *Festuca pratensis*. If slopes are excessively steep these plants are usually introduced behind small protective works which follow the contour. A very simple and successful type of work is made on the "living-dam" basis, using willows. The above-mentioned plants used in the early stages of slope-fixation are subject to heavy frost-lift and must have deep rooting systems capable of withstanding the strain placed on them. In this type of work, shallow-rooted species are of little account.

In the second stage local pioneer hardwoods are chosen to act as nurse crop to the softwoods which will be introduced later. Contour planting is the rule for these species and, where terraces have already been formed, the hardwoods are introduced behind them. Species which give good results under a variety of conditions of soil and climate are *Alnus incana, Alnus viridis,* and species of *Salix*. *Robinia pseudo-acacia* is often used also.

Consequent upon the work carried out in the earlier stages, some improvement in soil conditions can be expected, and now valuable softwoods can be introduced with reasonable success. Methods of introduction have varied during the one hundred year period in which conservation work has been carried out. Early workers favoured the broadcasting of seed over the slopes; present-day practice favours planting. Broadcasting has the advantage that large areas can be covered in a short time at comparatively low cost. Loss of seed due to the action of surface water or failure to germinate are serious disadvantages however. Only two species are widely introduced using this method at present. In both cases seed is broadcast on snow-covered slopes at the end of winter. The species concerned are *Larix decidua* and *Pinus uncinata*. The young seedlings, which germinate through a thin layer of snow in the spring, are insulated against sudden extremes of temperature and are thus better able to resist the action of frost-lift. Other species are only broadcast in favourable conditions.

Planting of one and two year stock is by far the most successful method for the introduction of such species as *Pinus austriaca, Pinus sylvestris, Pinus cembra, Picea excelsa,* and *Abies alba,* which are those most commonly used in conservation work. Where hardwoods have been planted on the contour, softwoods are introduced in furrows following the same lines. These furrows may be continuous on the contour, or short and staggered. Where slopes are not steep, planting is carried out using regular spacing.

Provenance of species used in this work is carefully considered, and if possible seed is collected in the area in which it is to be sown. Early setbacks, previously referred to, were the result of poor selection of both species and provenance. Often seed was collected in lowland areas for sowing at altitudes of 5,000 feet. In many cases, too, checks could be traced back to the use of planting stock from lowland nurseries so that it soon became a general rule that all stock was to be raised in the area in which it would later be planted. This resulted in the establishment of "flying nurseries", which were not only flying in name since many foresters placed a rather strict interpretation on the official decree. The desired result was achieved, however, and planting losses were considerably reduced.

The large scale plantings carried out in the past are in many cases approaching maturity today. Utilisation of most of the species is assured due to use of skilful felling techniques and advanced forms of transport, even in these remote areas. For some time, however, it appeared that there would be no outlet for the extensive stands of Austrian pine. This species was introduced on a large scale in dry southern Alps because of its ability to thrive on limestone country. This timber is not at all appreciated in France, and its value as mining timber, for which purpose it is quite good, was considerably reduced by the location of the stands. Further, the stands were planted in regions in which there were few forest-industries so that experimental marketing was difficult. It therefore appeared for some time that the plantations would not be remunerative. Recently, however, a large French company which specializes in the manufacture of wallboard and Kraft pulp, using *Pinus pinaster* from the Landes plantations, has announced its intention of setting up two mills to manufacture the same type of produce in the centre of the Austrian pine plantations.

The future of established forests is assured, not only because the products will meet with a steady demand in the future, but also because the species concerned regenerate freely after logging. There will thus be no need for expensive re-establishment. Prospects in catchments which have not yet been planted are far from bright however. Over the last twenty years there has been a steadily increasing drift of population, all over Europe, from the alpine regions to the cities. This can doubtless be explained by the better conditions of work offered in the cities and to the glamour of the "bright lights". The life of the mountain dwellers is hard, unexciting, and at times unrewarding, and it is not surprising that with the spread of education they should decide to seek their fortune in the towns. Be that as it may, the drift is established; it will have serious consequences for the Forest Service planting programmes. Planting in many regions is already impossible; foresters are already having recourse to less satisfactory methods of forest establishment, to the detriment of Conservation Plans.

B. *Sodding and Restoration Above the Tree-Line*

Correction of a catchment is only completed when all of the slopes of the upper basin have been stabilized. The importance of work above the tree-line is no less than that undertaken in other parts of the area. In Europe, these upper slopes support a substantial seasonal population. Work is therefore directed mainly towards the development or improvement of pastures.

Sodding is a way of ensuring that pastures are improved and that run-off is regulated at the same time. In practice, sods are taken from flat land at lower altitude and carried to the upper slopes where they are built up in the form of low terraces. In some cases, low stone terraces are built using material found *in situ,* and the terraces are capped with sods. These terraces are seldom continuous. Usually they are staggered on the slopes. They have a length of two to three yards and a depth of one to two feet. If the grass has been carefully selected, it readily adapts itself to the new conditions and its spreading cover breaks the force of run-off water, holding detritus in place.

Following this initial work the slopes are usually sown with the seed of the more valuable forage species. This operation is carried out by hand due to the difficulty of the terrain. Many European foresters engaged in conservation work expressed interest in New Zealand methods of aerial sowing. After sowing, the seed is usually covered to prevent loss by wind, water, or rodents. Once these operations are completed the areas are completely closed to grazing until there is a closed cover of vegetation. Best results are obtained through use of perennial plants. It would be beyond the scope of this article to enumerate the species used and the altitudinal zones to which they correspond. Suffice it to say that the matter has received much attention in Europe and that the species chosen can be introduced with every chance of complete success.

In catchments where work has been undertaken and where the cover on the upper slopes has been reconstituted, strict control is kept on grazing, depending on the time of the year and the state of the pasture. Work on pasture improvement, with the introduction of new forage plants and the eradication of weeds, goes on continuously. Strict limits are laid down to restrict the proportion of families in the following way:

Graminae	60%-90%
Leguminosae, Papilionaceae,	25%- 5%
Compositae	7%- 1%
Others	8%- 4%

Such work may appear to many to go beyond the realms of forestry, and indeed it is a little disturbing, at first sight, to see a forester, surrounded by a herd of cows, conscientiously examining grass roots, but the work has important implications nevertheless. It ensures that the forester, who is, after all, the person most concerned with the maintenance of stable watershed conditions, has the most complete knowledge of that watershed.

Work on the Outwash fan

With work on the fan the last stage in correction is entered. Until such time as work in the stream bed and the upper basin has been completed, there is little to be gained in attempting corrective measures on the fan. If the slopes have not been stabilized, and if the stream is still actively transporting detritus, there is every chance that any construction erected on the fan will be destroyed by floods. As soon as stabilization higher up has taken place, however, work on the fan must be undertaken immediately. The reason for this might not be obvious at first glance.

While the stream is engaged in transporting material along its course it has little erosive power on reaching the zone of reduced slope which corresponds with the beginning of the fan. Normally phenomena of deposition are common here and it is only in times of high flood that any quantity of material is transported over the length of the fan. Consequent upon damming higher up, however, the clear water which reaches the fan has a much greater power to erode; and this erosion constitutes a serious threat to the farms, villages, and communication lines established on the fan under a totally different regime. The risk of erosion is the higher because the stream is rarely entrenched in a permanent bed but wanders across the fan at will. Once the "clear water stage" of correction has been reached, therefore, there is a great amount of material on the fan which is potentially transportable.

The major task facing the forester in these final stages of correction is confinement of the torrent to a permanent bed on the fan, with protection of other areas against possible break-outs from this bed. The line of the proposed permanent bed usually follows the line of greatest slope from the mouth of the gorge to the principal river, although often it is necessary to diverge from this line because of the presence of farms which may have been established thereon during periods of inactivity of the torrent.

Where there is still some danger of the torrent bringing down debris across the fan in flood periods, the bottom and sides of the channel are paved with large flat stones so that debris is not deposited on the fan, blocking the course of the floodwaters, and causing a breakout. If the danger of transport is not high such paving is avoided because of its cost. Where no paving is done, the stream is contained in its bed by the use of dykes and groynes. Boulder-moving torrents are usually treated in this manner.

A rather special method is used in cases where the fan is not densely populated, or where there are no important communication lines to be protected. This method, known as the "silt-trap method", consists of diverting the torrent from its principal bed toward some unoccupied portion of the fan which has little value. Here the force of the floodwaters is broken by lines of closely-spaced willow and poplar cuttings. The material in suspension is dropped once the speed of the water falls, and in this way protection is afforded the cuttings, the ground being built up for a considerable distance around them.

When the water has passed this zone of traps, it is collected and led back to the principal bed by the use of dykes and stone walls. This method, which is extremely useful, is difficult in application and has not been in favour until recently. Difficulties are encountered in diverting the torrent at the mouth of its gorge and in finding an unoccupied portion of the fan in regions where the density of population is high. Nevertheless these difficulties are now often overcome in an effort to reduce silting of dams built for hydro-electric purposes.

In all cases correction of the fan is completed by plantations of forest trees. Of all the areas of a catchment which can be planted, the fan offers the best chance of success once the torrent is more or less entrenched in its bed. Soils here are infinitely better, the young plants have a better survival rate in the initial stages, and problems of extraction encountered higher in the torrent basin are non-existent. There are now some excellent stands of Scots and Austrian pine on this type of land in France, the result of correction measures undertaken eighty or ninety years ago.

Before leaving this subject it would be as well to describe a new type of construction which may well revolutionize torrent correction within the ensuing decade. This construction method has been devised by Genet, one of the leading French workers in the conservation field, for use primarily on small torrents. These small torrents which abound in alpine regions are rarely worthy of a series of dams in the classical style, yet the collective damage done by them is very great.

Genet's idea, in brief, is to let the torrent do as much work as possible, suppressing the outwash fan altogether. Genet argues that it is unreasonable to let something grow, and then be faced later with the need of protecting it, when its growth could have been stopped in its initial stages. In the case of small torrents the soundness of his reasoning is undoubted, for he has already corrected a number of these using his own technique. In place of a series of dams, Genet erects one dam where the torrent joins the principal river. The wings of this dam run back to the hill on each side of the gorge. This "basin-dam", as he calls it, contains the fan completely. The central part of the dam is of no great height and the main body of water is concentrated there. Height of the dam increases steadily away from this point so that, instead of the normal convex fan, a concave deposit is formed behind the dam. In this way later work to maintain the torrent in a permanent bed on a convex fan is avoided.

With this type of construction there is no danger of erosion on the fan, in the final stages of correction, as is normally the case, so that silting of hydro-electric dams downstream is considerably reduced. Such has been the success of the "basin-dam", on small torrents, that its use is now envisaged on larger streams. Needless to say this will call for some immense structures, but it may prove economical from a long-term point of view.

Although the number of dams is reduced using this system there is still need for the complementary works higher in the catchment; and planting and sodding are carried out in the usual fashion.

LAND USE BALANCE

In New Zealand, the question of land use in alpine and sub-alpine regions is seldom raised. It is generally considered that such areas are suited only to grazing, with the forest relegated to a secondary role of protection, agriculture playing no part at all. In France, and indeed over the whole of Europe, such problems are not so easily resolved due to the high population densities of these areas. France contains roughly twice the land area of New Zealand, yet the population is twenty times greater. Little wonder, then, that pressure for land is high even in these remote localities.

In any Correction Project careful consideration must be given to the conflicting claims of grazing, agriculture, and forestry. Thus it may happen that planting of the upper slopes which is considered necessary for complete stabilization of the soil may result in hardship to established graziers. In such a case, sodding, and pasture improvement, are undertaken instead, provided this does not result in extreme danger to down-valley inhabitants and works. This does not mean that established interests have complete power of veto in Correction Projects. Where the over-riding requirement is soil stability, and protection of inhabitants below, the Forest Service has the final say.

In these densely populated areas agriculture has its part to play; although here the problem is not as difficult as it is in the case of grazing. In general, little agriculture is possible above an altitude of 4,000 feet; conflict results only in the case of corrective measures on outwash fans. The problem here can nevertheless be extremely difficult. Often these fans are the only relatively flat land in the vicinity of the small mountain villages. They are used to supply the needs of the local population in vegetables, cereals, and winter feed for their stock. Their loss to agricultural production could mean the wholesale evacuation of the region by the inhabitants. Some of the depopulation of alpine areas has been caused by large scale afforestation. Speaking of a valley which had been completely planted following a long history of pastoral abuse, Guinier once said, "Better that grazing and agriculture had maintained the land in a suitable state with the forest in its natural place, than that the necessity arose to spread the forest over the entire valley." These words, spoken in 1890, convey an even greater message today when the increased demands placed on these marginal lands are considered.

From this brief account of land use problems it will be appreciated that the task of the forester engaged in conservation work is one which calls for detailed knowledge, not only in the field of forestry, but also in that of agriculture, particularly pasture management, and animal husbandry. Only long experience in work of this nature will permit the correct solution of any land use problem.