The development of the concept of steepland protection forestry in New Zealand

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Abstract

The notion of steepland protection forestry developed in Europe at the end of the Middle Ages. By the beginning of the nineteenth century destruction of montane forests in the French Alps and Pyrenees had caused serious flooding and erosion, requiring remedial engineering and revegetation measures. About this time there developed in Europe a great deal of scientific interest in forest influences which stimulated similar interest in North America and acknowledgement there of the importance of forests in controlling streamflow and erosion. European and American ideas about protection forests were transferred to New Zealand in the latter half of the nineteenth century and persisted here, little modified, until the 1960s. From then on there has been a great deal of New Zealand research in relevant scientific disciplines which has coalesced to provide a wider context for the study of forest influences in this country. Now the former simple concept of steepland protection forestry imported from overseas has been replaced by more complex ideas, about which there is still debate.

The development of the technology of forestry in nineteenth century New Zealand was nurtured from the concepts held and the experience gained in Europe and North America. The importance of protection forestry in that technology was soon acknowledged here. It is useful then, in any examination of the notions about steepland protection forestry which have guided events in New Zealand, to start with what happened before in Europe and America. (It would be wrong though to imply that protection forestry was a purely western 'discovery'; in China there was a governmental Commission of Mountain Forests with protective rules and regulations before 250 BC (Teng, 1927).)

Early work in Europe

Protection forestry was probably initiated officially in Europe in Switzerland; there in 1342 the first 'ban' (permanent protection forest) was proclaimed to protect a mountain valley community from the consequences of peasants destroying montane forests to extend their pasturage. However it was the French who were the real pioneers, providing impetus for much of the practical protection forestry work in Europe by developing successful restorative techniques after extensive deforestation in the mountains (Kittredge, 1948). (France had long led the way in general forest conservation with its celebrated forest ordinance of 1669 drawn up by Colbert, one of the ministers of Louis XIV (Fernow. 1907).)

The French Revolution, with its overthrow of all sorts of restraints, initiated a period of overcutting and forest destruction all over France. The impact of this forestry laissez-faire was particularly damaging on montane slopes in the French Alps and the Pyrenees where forests were exploited to destruction to provide grazing for land-hungry peasants (Lowenthal, 1965). In the first half of the 19th century the French engineer Surell and the French forester Demontzey developed torrent-control techniques in the Alps and Pyrenees, comprising the engineering works of dykes and dams, and the vegetational techniques of planting, wattling (pegging brush down on beds of headwater drainage channels) and sodding (repairing erosion scars in montane grassland with turf) (Morris, 1955). In fact Demontzey (1880) wrote a reforestation 'classic' with 'before' and 'after' photographs covering 20-40-year time-spans.

About the same time as this important practical work, there developed in parts of Europe deep scientific interest in the physical influences exerted by forests. In 1853 the French climatologist Becquerel published a comprehensive memoir on the subject (Kittredge, 1948). It comprised discourses on many facets in which he cited the observations, which included a little general quantitative data, of a range of authorities from their work in Europe and in other countries, including Algeria, Venezuela, and USA, and drew conclusions from some of them (Becquerel, 1869). A few of his inferences sound odd today; for instance, he thought that forest belts can remove "miasmas" from "infected" air as it blows through them, citing the protection afforded against malaria by screens of trees near the Pontine marshes in Italy.

Becquerel's conclusions about the influence of forests on hydrology and erosion are more relevant here: Forests cause more precipitation to be absorbed by the soil and so reduce runoff. Forests can cause orographic rain (although he did not use that term). Evaporation is less from a forested surface than a grassed one. Extensive forest clearing reduces water supplies from springs and streams (he was not clear why). Forests conserve water and regulate the rate of flow. In the mountains the role of forests is particularly important and the restoration of montane forests is a prime necessity. There they reduce runoff, by causing greater infiltration into the soil, and prevent the development of torrents. Also they stabilise the soil with their roots, so reducing erosion (Becquerel, 1869). The conclusions of Becquerel were criticised by some of his European contemporaries who denied that afforestation would have any effect on stream flow. This was probably the start of the long controversy about the effect of forests on stream flow and floods (Kittredge, 1948), which probably inspired the European foresters to set up experiment stations in their forests, first in France and Germany in 1867, to collect forest meteorological data (Schlich, 1906).

Early ideas in USA

The scene now shifts to North America. In 1864 there burst upon educated Americans a remarkable book which had a huge impact and which, within a decade, had achieved an international reputation. George Perkins Marsh was a scholar of near genius; he had a grasp of 20 languages, a formidable memory and an ability to synthesize much of what he per-

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ceived. It is hard to reconcile these capabilities with a self-trained lawyer from a small town in Vermont who suffered from persistent eye trouble and who was demonstrably a poor businessman. (However, he so impressed President Lincoln with his scholarship that he was appointed as minister plenipotentiary to the new Kingdom of Italy in 1861 and remained in that post till he died in 1882). His book "Man and Nature" has been described as "the fountain head of the conservation movement" and he is credited as being the originator of the phrase 'forest influences'. Marsh wrote of the cumulative abuse by mankind of what we now call the environment. His main theme was that man had used it in an exploitive, abusive way, consuming the earth's resources profligately despite them having been given to him only to use without destruction or waste. The whole force of the book is altruistic; it is predicated on the philosophy that the welfare of future generations is more important than the gratification of the wants of the current generation (Lowenthal, 1965). He was probably the first global environmentalist.

Forest destruction was an anathema to Marsh because he saw it as being pivotal to the degradation of the earth. He wrote of the consequences: "The face of the earth is no longer a sponge, but a dust heap, and the floods which the waters of the sky pour over it hurry swiftly along its slopes, carrying in suspension vast quantities of earthy particles which increase the abrading power and mechanical force of the current, and augmented by the sand and gravel of falling banks, fill the beds of the streams, divert them into new channels and obstruct their outlets. The rivulets, wanting their former regularity of supply and deprived of the protecting shade of the woods, are heated, evaporated, and thus reduced in their summer currents, but swollen to raging torrents in Autumn and in Spring..." Whereas: "The surface of a forest, in its natural condition, can never pour forth such deluges of water as flow from cultivated soil..." Marsh's approach in his book was exhaustive, drawing upon the observations of an extraordinary number of authorities from many countries, including Becquerel. He paid the latter the tribute of acknowledging that his "....treatise on the climate effects of the destruction of the forest is the fullest general discussion of that subject known to me...." Marsh's approach was inductive too, generalisations coming after the consideration of specific cases. It was also discursive and digressive, the latter to an eccentric degree by modern standards. It had an immediate effect on US forestry, drawing attention to the destructive exploitation of American forests and the need to follow a different course. "Man and Nature" led to the establishment in 1873 of a national forestry commission and some government forest reserves (Lowenthal, 1965). Later Gifford Pinchot (1947) called the book, "epoch-making".

1877-1912 was a period in America in which there was a spate of propaganda about the 'catastrophic' effects of deforestation and exaggerated claims about the beneficial influences of forests, with little scientific evidence adduced. Reaction came in the form of opposition from the US Army Corps of Engineers and the US Weather Bureau who claimed the impact of forests on stream flow to be insignificant. It came also from the US Geological Survey who stated that forests were also insignificant in the control of erosion (Kittredge 1948).

In the background for much of this period and ever objectively seeking the truth about forest influences was the German-educated forester B.E. Fernow, the man who initiated scientific forestry in North America. From 1886 to 1898 he was chief of the Forestry Division of the US Department of Agriculture, when he was succeeded by the more charismatic and politically effective Gifford Pinchot (Pinkett, 1970). By 1887 Fernow had, in the absence of definitive findings, reached a tentative hypothesis about forests, stream flow and floods. It was, typically, a balanced view. He accepted the precipitation-absorbing and erosion-reducing role of forests, and their regulatory effect on stream flow. He stated that forests alleviate the dangers of abnormal floods and reduce the number and height of regular floods. However he did concede that really heavy rainstorms overwhelmed the effects of vegetation, and also that the locations of the mouths of tributaries have a determining role on the severity of flooding in main channels (Rodgers, 1968). Gifford Pinchot accepted these points when he became head of the US Forest Service (as the Division came to be known) but, doubtless for political reasons, sometimes assumed an ambivalent stand, implying that reforestation could lower flood crests significantly (Schiff, 1962).

The controversy about forests and floods continued in America and so the US Forest Service did what the German and French foresters had done over 40 years before; they commenced the systematic collection of forest meteorological data at forest experiment stations, established in five regions between 1908 and 1912 (Kittredge, 1948).

Early New Zealand understanding

Meanwhile, back in New Zealand in the 1860s and 1870s, Marsh was being read. In 1868 Thomas Potts, the Member of Parliament for Mount Herbert, got up in the House to complain about the extant rate of forest destruction and, citing Marsh, said he believed that recent flooding of the Hutt River was due to forest clearance there (Potts, 1868). The engineer/explorer Arthur Dudley Dobson had read Marsh too, and referred to him when warning about flood damage to productive riparian land, and pointing out the role of forests in lowering flood peaks (Dobson, 1871). The first Conservator of Forests in New Zealand, Inches Campbell-Walker, cited Marsh in the comprehensive report he made to the Government before he resigned in 1877 (Campbell-Walker, 1877). He had no doubts about the role of forests in regulating stream flow and reducing flooding, ensuring the permanency of water supplies, and controlling erosion through the mechanical influence of tree roots. However he was careful not to claim that the presence or absence of forests in a district altered the total amount of precipitation falling there, regarding this feature as non-proven (Campbell-Walker, 1876).

The Report of the 1913 Royal Commission on Forestry clearly recognised the value of protection forests, terming them "climatic reserves", which should be safeguarded and kept intact to protect the soil, conserve water and prevent floods. An overseas authority quoted in the Report was Fernow who was cited as attesting to the capability of forests to regulate stream flow by contributing subterranean drainage via the forest floor cover, to reduce erosion and thus aggradation further down the drainages, and to reduce flooding. Of interest in the appendices to the Report is the evidence of C.A. Cotton, the father of New Zealand geomorphology but then a young lecturer at Victoria University College. Cotton reported, inter alia, that he had seen cleared, grassed steep slopes slip after a while, presumably because the old tree roots had rotted. The Report of the Commission represented well the views then of informed New Zealanders about the protective role of forests. For instance, eight years earlier the chief forester of the Forests Branch of the Lands Department had written of the importance of protection forests in lowering flood peaks in spring and maintaining stream flow in summer and autumn (Matthews, 1905). And in Parliament, in a major speech on the Report of the Commission, G.M. Thomson spoke, inter alia, of the possibility of planting up denuded Canterbury watersheds to conserve water supplies and lower flood peaks (Thomson, 1914).

To cut a long story short, by the time the Forest Service was established in 1920 – and the first Director, L. McIntosh Ellis, had been a forestry student of Fernow's at the University of

Toronto (Ellis, 1919) – the notion of the nature and functioning of protection forests in New Zealand had become established. They were regarded as analagous to giant sheets of sponge which lay over the steep terrain, absorbing the precipitation and releasing it slowly to the river systems, so smoothing out the extremes of flow, lowering the peaks of floods and raising the low flows of dry periods, and also preventing or reducing erosion. It was the general concept held in Europe and North America.

New Zealand advances in forest hydrology

This conventional wisdom about forests and floods persisted for several decades. Then, slowly, New Zealand scientists began to emulate what had been done in Europe and USA by taking a more quantitative approach to field hydrology and establishing studies in small catchments covered with forest, scrub and grassland to ascertain the water balances; first at Taita near Wellington, shortly after at Craigieburn in Canterbury and later at places like Central Otago, north Westland, south Nelson, Coromandel, east Otago, Moutere and near Rotorua. This form of research developed slowly in the sixties, stimulated by the International Hydrological Decade programme. Then, in the early seventies, forest facets of it received considerable momentum because of acute environmental controversy over the proposal to utilise extensive areas of lower altitude South Island beech forests and replace a segment of them with radiata pine. The burgeoning environmental movement foresaw disastrous hydrologic consequences from the proposed enterprise. Objective quantitative answers were needed to assess the risk and so Governmental funds were made available for the research required.

The results of this medium-term hydrologic research, when they became available some years later, were responsible for a revolutionary change in our understanding of the hydrologic role of forests in New Zealand. One surprising feature was that no marked difference was found between the indigenous and exotic forests in their use of water. Both have a substantial interception effect which exceeds the transpiration value, and this really was most surprising. ('Interception' refers to the precipitation which is caught by tree canopies and evaporated back to the atmosphere before it can fall to the ground. In the catchments studied it was found to vary between 25% and 37% of the total precipitation (O'Loughlin, 1986).)

In the indigenous protection forests it was found that the often intense rain, the commonly steep slopes and the highly permeable soils result in quick responses to rainstorms, markedly different from the situation in other parts of the world where runoff from forests has been studied (Pearce and McKercher, 1979). In other words the hydrologic 'delaying' effect of New Zealand forests was found to be much less than had been thought. Certainly the presence of these forests would appear not to influence the flood peaks following very large storms, i.e. those that could be expected to occur once every ten years or less frequently (O'Loughlin, 1986).

Indeed forests in New Zealand appeared to have more influence over water quality than water quantity. The quality of water flowing from catchments clothed with either indigenous or exotic forest was found to be high with few suspended solids and low concentrations of nutrients. There was found to be a significant potential threat to water quality during logging, from concentrations of sediment emanating from the construction of forest roads and skidder tracks, and from logged unstable slopes. Clearfelling, in either indigenous or exotic forest, caused only small changes in the chemical content of stream-water. However, where the logging was followed by burning there were significant but short-lived pulses of K and nitrate-N coming from the catchments (O'Loughlin, 1986).

All in all, in terms of water regimes, that notional giant sheet of sponge seemed much thinner.

New Zealand research into slope stability

Since the thirties and forties there have been great advances in our understanding of the New Zealand physical environment, advances to which many disciplines have contributed, especially: geography, meteorology, hydrology, geology, botany, forestry and palaeobiology. This progress is germane to our modern view on the influence forests have on slope stability, i.e. steepland erosion, because it has enlarged the context of the study. Of particular relevance are the advances in our understanding of New Zealand tectonics and mountain-building, volcanicity, landforms, weather patterns, and vegetation changes since the Pleistocene. Research findings in these disciplines have impinged on one another and coalesced to provide an integrated perspective for our views on the stabilising role of protection forests.

We know now something of the rate of uplift in our mountain systems: an astonishing 20mm per year in the Mount Cook region, much less in other parts of the South Island, ranging from over 5mm per year in the Kaikoura Ranges to 0.5 to 1.0mm in the foothills of eastern Canterbury; estimated rates up uplift in the North Island for some mountains in the Rimutaka/Raukumara axis lie between 3 and 5mm per year (O'Loughlin and Owens, 1987). There are two main general implications. First, with such a fast rate of mountain-building, rapid erosion is inevitable. Second, the associated seismic activity has undoubtedly triggered many large-scale avalanches which would have demolished much forest.

We have a much better idea too of the sediment yields from our mountain systems. Indeed one of the highest sediment yields in the country comes from the forested northern Ruahine Range: more than 4500 cubic metres of detritus per square kilometre per year (Grant, 1982) – high even by world standards. And we know that a lot of sediment from past erosion has been stored, often for thousands of years in landforms close to the rivers such as terraces and fans (Mosely, 1978). Also many of the spectacular screes which are such a common feature of the eastern side of the South Island mountains are not all indictments of the pastoralists' management; they could have been in existence in much the same form as they are now for long periods of time, and may be relatively stable (McSaveney and Whitehouse, 1987). The lesson is that there is not always a simple relationship between the current condition of the protective vegetation in headwater catchments and the sediment loads now being carried by rivers.

Rainfall is considered by some to be the dominant influence on erosion rates (McSaveney, 1978); so it follows that the regional rates of erosion should differ widely too. There is strong evidence of cycles of storminess in New Zealand weather, with eight stormy periods being recognised during the last 1800 years. The stormy periods have resulted in depletion of vegetation, increased rates of erosion and alluvial sedimentation, while the intervals separating them have provided respites for soil formation and recovery of the vegetation. An interesting feature of the theory is that it has been claimed that the total amounts of sediment deposited in successive stormy periods up to the present have generally decreased, even though man has been present in New Zealand for the last six; the implication is that the changes he has wrought have been less destructive than nature (Grant, 1985; 1987).

The influence of forest on slope stability

It is clear that it is the high-intensity, low-frequency storms which initiate the mass movements that occur under a forest canopy on steep slopes. Erosional debris dislodged by these storms builds up in the beds of low-order tributaries, often held there behind the boles of large trees carried downslope with the soil and rock material. Research in north Westland has shown that storms with return periods greater than five years transport most of the soil and rock debris from forested slope to stream bed (O'Loughlin et al, 1978; Pearce and O'Loughlin, 1978; O'Loughlin et al, 1982).

It is now generally accepted too that forests are not always an effective barrier to erosion, and that large storms can overwhelm their stabilising influence. Indeed, in some regions of tectonic instability and regularly heavy rainfall, that there is a more or less continuous vegetative cover up to altitudinal limits may be interpreted more as an indication of effective colonisation of eroded surfaces by resilient forest and other species, rather than of the protective efficacy of the vegetation (Basher et al, 1987). At the same time there are many examples of steep slopes being held intact under forest which must have withstood many high-intensity storms. For instance, before slopes had been cleared of forest in the headwaters of the Waipaoa River, which flows through Gisborne, they had been stable, at least throughout the life-times of the larger trees which represented periods of several hundred years (Gage and Black, 1979). And, in a reverse example, clearfelling of podocarp-hardwood forest followed by burning in the Grey Valley of north Westland, over a large area on formerly stable, steep slopes underlain by late-Tertiary sandstone, resulted in spectacular erosion, representing an increase of more than an order of magnitude (Pearce and O'Loughlin, 1978). Severe slipping has occurred on steep slopes in Northland, Coromandel Peninsula and the Marlborough Sounds, where heavy rain had fallen after the clearfelling of stands of mature radiata pine (O'Loughlin and Owens, 1987). These findings are generally similar to those overseas, viz that the removal of a forest cover can increase the rate of erosion by one, two or even three orders of magnitude (Pearce and O'Loughlin, 1978).

During the seventies and the early eighties detailed research in New Zealand elucidated how tree root webs stabilise slopes. Vertical roots nail loose, upper soil horizons to stable subsoils; ramifying roots supply lateral cohesion and rigidity to upper soil layers which hold weathered mantles in place; and large structural roots act as buttresses, both reinforcing individual trees and stiffening further the upper soil horizon. Resistance to soil shear (slipping) was found to vary linearly as root biomass, the more and bigger the roots the less the susceptibility of the soil to erosion. Further, forests improve slope stability by keeping soils drier than would be the case under low vegetation (O'Loughlin and Owens, 1987).

A range of investigations has shown that indigenous and mature exotic forests ensure stability on steep slopes under most conditions except after long periods of extremely heavy rainfall when soils become saturated, with depressions where sub-surface water accumulates being most susceptible to failure. When forest is removed from slopes over 30 degrees even moderate storms may induce shallow slipping; slopes where soils are shallow and lie over impermeable substrata are the most likely to fail. There may be slumps and earth flows on easier slopes, even less than 25 degrees, on the soft-rock terrain of the eastern North Island (O'Loughlin, 1986).

The significance of different time scales

There is apparent a conflict in some of what has been written above. Some New Zealand scientists have provided evidence supporting their contention that long-term regional erosion rates depend primarily on abiotic factors, on storminess and associated torrential rain, on mountain-building and related earthquakes. They have said that the influence of vegetation and the consequences of changes wrought in the vegetation, for example by deer and possums, are of much lesser significance. A conceptual trend has been recognisable; one in which less emphasis has gradually been given in protection forestry to off-site benefits from the forest stands, and more to the importance of preserving the plants, animals and soils in the stands; in other words more emphasis is being placed on the inherent value of the protection forests as forests. Indeed there is the point of view that vegetation is irrelevant to erosion rates in the mountains (Caughley, 1983). (One can envisage conscientious protection foresters, groggy on the ropes in interdisciplinary tussles, wondering about the rationale of their work and becoming more and more doubtful of the erosion-controlling efficacy of protection forests.)

Yet a lot of good forestry research has shown the significant, positive influence of forest vegetation on slope stability. Is the issue one of location, of protection forests playing a significant role in some regions and not in others? (Caughley (1983) made the distinction between **soil** erosion in less steep country or in the lowlands where vegetation is significant, and **rock** erosion in the mountains where it is not.) Is the issue simply one of degree, of protection forests playing a significant role only in times of non-extreme events? Or is it a combination of both?

There has been offered recently another reconciliation, one which recognises two time scales, one geological and the other short enough to be relevant to the affairs of extant communities. It has been suggested that protection forests, and protective vegetation in general, have a significant influence on rates of erosion in the shorter term, one which is measured in decades and so is more meaningful to people. It has been pointed out, as an example, that the presence of forest cover reduced in situ the amount of landslipping induced during Cyclone Bola by about 96%. This check to erosion may not be meaningful when viewed on a geological time scale, but it is meaningful when viewed on the time scale with which the people living in Gisborne City and District are mainly concerned (Benecke and Allen, 1991).

More recently still Allen (pers. comm.) has suggested that the apparent inconsistencies in protection forest influences arise also because particular influences, and their complex interrelationships, vary with site conditions. What is needed is a conceptual framework to analyse such variation, and this could well be provided by the dominant environmental gradients.

The development of the concept of steepland protection forestry in New Zealand has long reached a stage of complexity where the analogy of giant sheets of sponge is unsatisfying. It is clearly now beyond the stage of being represented by any simple notion. This has become so because of the better understanding we now have of the breadth of the subject, an understanding provided by the fusion of research results from a range of related scientific disciplines. It seems necessary too, in order to reach a satisfying working hypothesis, for particular influences to be related to site conditions, and for consideration of time scales to be injected into the science mix.

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References

Adams, John (1980) High sediment yields from major rivers of the western Southern Alps, New Zealand. Nature Vol. 287: 88-99.

Basher, L.R.; Tonkin, P.J.; Daly, G.T. (1978) Erosion and plant succession in a high rainfall area of central Westland. New Zealand Journal of Ecology 10: 160-161

Benecke, U. and Allen, R.B. (1991) New Zealand's mountainland forests: their use and abuse. In: Yang Yupo and Jiang Youxu (Ed.): IUFRO Project Group P1.07-00: Ecology of Subalpine Zones, Chendu, China (in press).

Becquerel, A.C. (1896) Forests and their Climatic Influences. Report of the Smithsonian Institution 1869, General Appendix: 394-416. (Translated by the Smithsonian Institution from Atlas Meteorologique de l'Observatoire Imperial, Folio, Paris 1867)

Campbell-Walker, I. (1876) The Climatic and Financial Aspect of Forest Conservancy as applicable to New Zealand. Transactions of the New Zealand Institute, Appendix: xxvii-xlix.

Campbell-Walker, I. (1877) Report of the Conservator of State Forests for the Organising and Working of the State Forest Depart-

ment. Appendix to the Journal of the House of Representatives C-3.
Caughley, Graeme (1983) "The Deer Wars". Heinemann.
Commission on Forestry (1913). Report of Commission on Forestry. Appendix to Journal of House of Representatives. (1913). C-12.
Demontzey, P. (1880) "Studien uber die Arbeiten der Wiederbewaldung und Berasung der Gebirge." Carl Gerhold's Sohn, Wien pp. 381.
Dodson, A.D. (1871) On the destruction of land by shingle-bearing rivers, and suggestions for protection and prevention. Transactions of the New Zealand Institute 4: 153-7.
Ellis, L.M. (1919) Candidature of L.M. Ellis for the Post of Director of Forestry, National Archives, Wellington.
Fernow, Bernhard E. (1907) "A Brief History of Forestry. In Europe, the United States and Other Countries." University Press, Toronto.
Gage, M. and Black R.D. (1879) Slope stability and geological investigations at Mangatu State Forest. New Zealand Forest Service. Forest Research Institute. Technical Paper No. 66.
Grant, P.J. (1985) Major periods of erosion and alluvial sedimentation in New Zealand during the late Holocene. Journal of the Royal Society of New Zealand 15 (1): 67-121.
Grant, Patrick J. (1987) A model for the late Holocene histories and interactions of climate, erosion, alluvial sedimentation, vegetation, Polynesians and animals. New Zealand Journal of Ecology 10: 160.
Kittredge, Joseph (1948) "Forest Influences." McGraw-Hill.
Lowenthal, David (1965) Editor of 1965 reprint of "Man and Nature" by George Perkins Marsh, 1864. Introduction: ix-xxix. The Belknap Press of Harvard University Press.
Marsh, George P. (1864) "Man and Nature; or Physical Geography as Modified by Human Action". Scribner, New York. (Reprinted 1965 by The Belknap Press of Harvard University Press.)
Matthews, Henry J. (1905) "Tree Culture in New Zealand." New Zealand Government Print.
McSaveney, M.J. (1978) The magnitude of erosion across the Southern Alps. Proceedings of the Conference on Erosion Assessment and Control in New Zealand, Christchurch, August 1978: 7-24.
McSaveney, M.J. and Whitehouse, Ian E. (1978) Anthropic Erosion in the Canterbury Mountain Lands. New Zealand Journal of Ecology 10: 160.
Morris, J.Y. (1955) Soil Conservation Practices in France, Part 1. New Zealand Journal of Forestry 7(2): 12-25.
Mosley, M. Paul (1978) Erosion in the Protection Forests. Proceedings of the Conference on Erosion Assessment and Control in New Zealand, Christchurch, August 1978.
O'Loughlin, C. (1986) Forestry and Hydrology. In "1986 Forestry Handbook", New Zealand Institute of Foresters.
O'Loughlin, C.L. and Owens, I.F. (1987) Our Dynamic Environment. In "Southern Approaches: Geography in New Zealand", New Zealand Geographical Society.
O'Loughlin, C.L.; Rowe L.K.; Pearce, A.J. (1978) Sediment yields from small forested catchments North Westland-Nelson, New Zealand. New Zealand Journal of Hydrology 17(1); 1-15.
O'Loughlin, C.L.; Rowe, L.K.; Pearce, A.J. (1982) Exceptional Storm Influences on Slope Erosion and Sediment Yield in Small Forest Catchments, North Westland, New Zealand. Proceedings of the First National Symposium on Forest Hydrology, Melbourne, May 1982: 8pp.
Pearce, A.J. and McKerchar, A.I. (1979) Upstream Generation of Storm Runoff. In "Physical Hydrology, New Zealand Experience". New Zealand Hydrological Society Toebes Memorial Volume.
Pearce, Andrew J. and O'Loughlin, C.L. (1978) Hydrologic and Geomorphic Processes in Forested Lands – A Selective Overview. Proceedings of the Conference on Erosion Assessment and Control in New Zealand, Christchurch, August 1978.
Pinchot, Gifford (1947) "Breaking New Ground." New York: Harcourt, Brace and Co.
Pinkett, Harold T. (1968) "Gifford Pinchot Private and Public Forester." University of Illinois Press.
Potts, T. (1868) New Zealand Parliamentary Debates. 1868,4.
Rodgers (111), Andrew Denney (1968) "Bernhard Eduard Fernow. A Story of North American Forestry". Hafner Publishing Co.
Schiff, Ashley L. (1962) "Fire and Water. Scientific Heresy in the Forest Service". Harvard University Press.
Schlich, Sir William (1906) "Manual of Forestry: Volume 1. Forest Policy in the British Empire". Bradbury Agnew and Co., London.
Teng, Shu-chun, (1927) The Early History of Forestry in China. Journal of Forestry 25: 564-570.
Thomson, G.M. (1914) New Zealand Parliamentary Debates. 1914, 168.

Forestry in Shaanxi Province, People's Republic of China – the part played by Yanan Zhengxian

He Zhengxian

Shaanxi Province is a long, narrow region running from north to south in central China. A mountainous area, Qinglin Mountain (3372m), lies across the central part from west to east, dividing the province into two parts. Watersheds to the south of the mountain drain into the Yangtze; north of Qinglin they drain into the Yellow River. Since the mountains restrict the airflow moving north, the climate becomes drier and colder from south to north. This results in three distinct climatic and phytographic zones.

1) The semi-arid sand dune area along the central part of the Great Wall.
2) The loess plateau, which covers 100,000 km^2 in the centre of Shaanxi, and which constitutes the forest steppe region.
3) The country south of the mountain barrier which has mixed deciduous and evergreen broad-leaved forest.

From the north to the south, minimum winter temperatures range from to -28°C to -12°C (mean -9°C to -20°C), and maximum summer temperatures from 32°C to 38°C (mean 18°C to 26°C).

Serious soil erosion exists in all parts of the province. The total area being eroded is 137,000 km^2, equivalent to 70% of the total area. Annual loss of silt is 9 million tonnes, about 8 million of which comes from the loess plateau in central Shaanxi. A strategic plan has been drawn up for soil conservation. This contains different afforestation and management methods for the different geographic regions.

In the north of the province, windbreak and sandbreak shelter belts have been established using native or naturalised trees such as saxoul *(Haloxylon ammodendron),* Russian olive *(Elaeagnus angustifolia),* Tamarix *(Tamarix chinensis),* and locust *(Robinia pseudococacia.)* More recently *Pinus silvestris* var *mongolica* has been extensively planted with better results.

In the north of the loess plateau, attempts were made to establish soil conservation forests of Chinese pine *(Pinus tabulaeformis), Platyculadus orientalis, Ulmus pumila, Hippophaë rhamnoides,* and *Robinia pseudoacacia.* As annual evaporation

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