4. Water Resources and Water Related Disasters in New Zealand : the Role of Agro-environmental Education

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Quantifying New Zealand's water resource

On a world scale New Zealand has plenty of fresh water, but it does experience severe climatic and hydrological extremes. New Zealand has a maritime climate, with the prevailing westerly winds delivering moisture-laden air from the Southern Ocean and Tasman Sea. The mountainous spine of the country is oriented perpendicular to this airflow, resulting in substantial orographic rainfall, especially on the western parts of both the North and South Islands (Fig. 1). In addition, tropical and sub-tropical cyclones frequently track south toward New Zealand in the summer and autumn months. High rainfall, steep topography and a high density of rivers generate high runoff.

There is a substantial rainfall gradient with high rainfall in the west (up to 10 m) and rain-shadow zones in the east (as low as 400 mm/a). In addition to this spatial variability, there is also a degree of temporal variability in rainfall receipt. Seasonality is not as strongly marked in New Zealand's rainfall regime compared with most other Pacific Rim countries, with most areas receiving reasonably well-distributed rainfall throughout the year. However, New Zealand does experience inter-annual and decadal variability in rainfall as a result of the El Niñ Southern Oscillation. As Fig. 2 illustrates, this is pronounced in the drier eastern regions. Because they have lower annual rainfalls anyway, substantial negative deviations from average can mean drought. On decadal timescales these droughts can be punctuated by periods of storminess (Page & Trustrum 2000). As with rainfall, the runoff regime is variable, with frequent flood events alternating with periods of low flow, as indicated by the coefficients of variability given in Fig. 3.

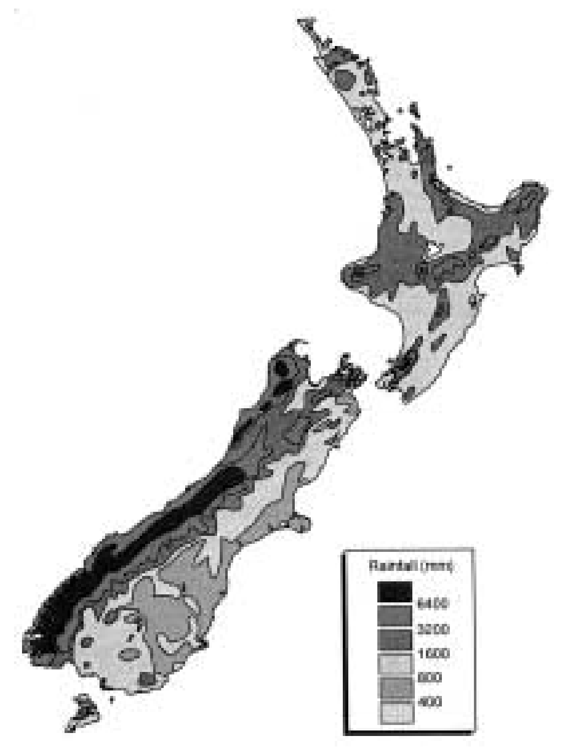

Fig. 1 Average annual rainfall (mm) (Source : Tomlinson 1992).

A century of anthropogenic disruption to the hydrological regime

In the mid to late 19th C, European settlement led to extensive deforestation and conversion to pasture over large areas of New Zealand. Much of this conversion took place on steepland litholo-

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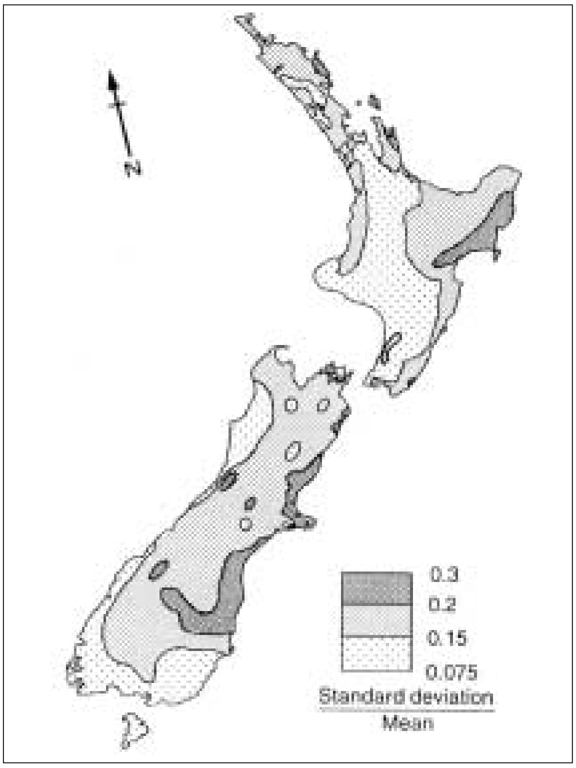

Fig. 2 Variability of average annual rainfall (Source : NZ Meteorological Service 1985, after Mosley & Pearson 1997).

gies naturally predisposed to erosion. Deforestation, in combination with naturally high and frequent rainfall, initiated a particularly intense phase of anthropogenic erosion that destabilised the landscape and led to extensive aggradation of river systems in response to the increased sediment inputs (Page & Trustrum 1999). These dramatic landscape transformations and associated erosion have progressively reduced topsoil regolith depths. The effect of this is decreased soil water storage capacity on hillslopes, which makes soils more susceptible to either saturation or desiccation than their forest antecedents. Runoff is therefore more likely to be delivered as overland flow than as through flow (Trustrum & De Rose 1988). A consequence of this is a long term change in the runoff regime, with a greater frequency of extreme high and low flows.

Fig. 3 Mean flows (m^3/s) and coefficients of variation of major New Zealand rivers (from Duncan 1992).

Cultural and economic values of water in New Zealand

Maori people, many of whom live in these highly degraded steepland areas, draw a close connection between the wellbeing of the people and the environmental state of the land and rivers (Harmsworth et al. 2002). This connectivity is embraced in the following quote from a Maori woman : “the river is our taonga (treasure) and our life essence. Land erosion reflects how we are becoming as a people. We are losing our mana (prestige/authority/honour). The river is eating away at the land. Without this land we are nothing”. This quote illustrates that in the New Zealand context cultural and ethical considerations are fundamental to the way in which the water resource is managed.

The variable distribution of New Zealand’s abundant water resource raises water allocation issues, even for a country with a population of only ~4 million with nearly the same land area (270,000 km^2) as Japan (population 125 million). Water contributes directly to New Zealand’s economic performance. The economic value of ecosystem services provided by New Zealand rivers and lakes (including hydroelectric generation, irrigation, waste processing and water supply) is estimated to be $\$US_{2002}$ 4,300 million per annum representing ~11% of New Zealand’s GDP (Patterson & Cole 1999).

In New Zealand, where 70% of the population is concentrated on the floodplains and lower reaches of rivers (Fig. 4), there is a high demand on the water resource for irrigation, domestic consumption and waste water treatment. This demand often exceeds the available resource. For example, although the use of water for processing waste represents only 8% of the ecosystem service value, critical limits to the ability of rivers to

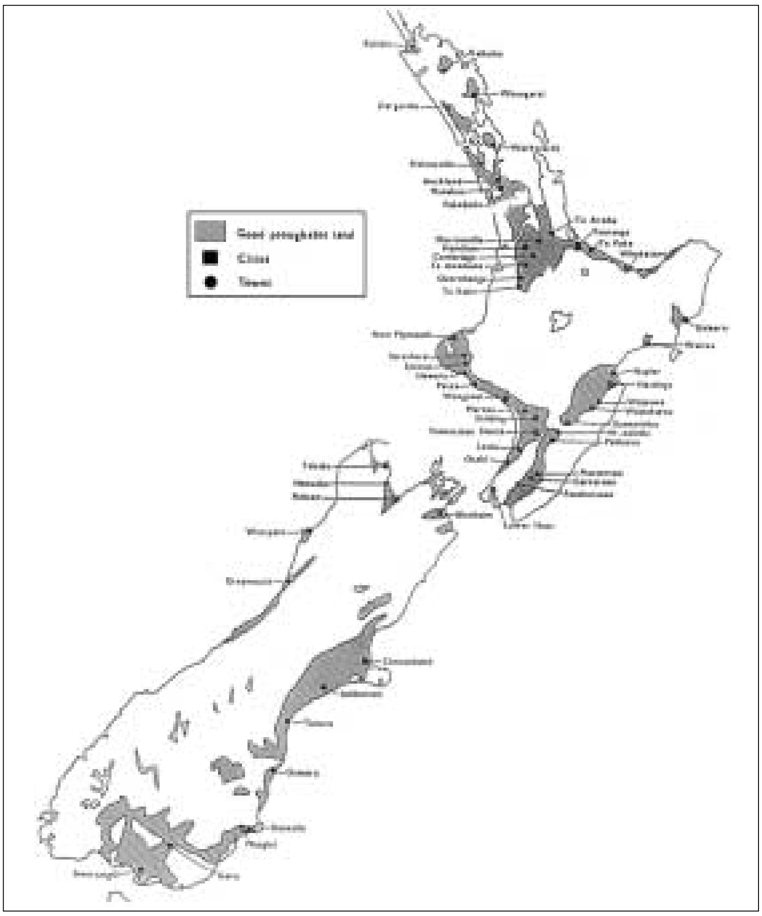

Fig. 4 Location of main population centres of New Zealand situated on floodplains (Source: Report of the Royal Commission to Inquiry, New Zealand, 1949. Govt. Printer, Wellington)

absorb waste are often reached (Patterson & Cole 1999). The resulting pollution and degraded water quality represent a long-term problem for ecosystem recovery because mitigation and rehabilitation programmes must take into consideration social and economic factors such as property rights.

Floods and Droughts

Ironically, this variability of water supply also represents a hazard and a cost to New Zealand in the form of water-related diasters such as floods and droughts. Almost all New Zealand's population centres are situated on floodplains (Fig. 4), and have been subject to some degree of flooding at various times. Annually flood damage costs about $\$US_{2002}$ 55 million (Krausse *et al*. 2001), and this has led to considerable expenditure on flood protection, with about $\$US_{2002}$ 1.06 billion spent over the period 1951/84 on remediation and mitigation (Waugh *et al.* 1997).

The significance of droughts in New Zealand is less well documented, at least in part because drought tends to be regional rather than localised in its impact. It is difficult to quantify the frequency of drought, although the distribution of rainfall variability given in Fig. 2 can be used as a broad indication of susceptibility. It does seem that somewhere in New Zealand will experience drought every 2 or 3 years (Waugh *et al*. 1997). Equally, it is difficult to quantify the costs associated with drought although farmers have traditionally been only too aware of their economic importance. For example, the 1988/89 drought on the eastern South Island cost farmers some $\$US_{2002}$ 227 million in lost production that would have included direct stock losses and lost primary productivity (Waugh *et al*. 1997). A major cost is reduced hydroelectric generation capacity. This is especially significant for the large South Island hydroelectric schemes where a "power crisis" in 1991/92 and more recent water supply deficits have highlighted the vulnerability of New Zealand's hydroelectric capability when "dry winters" are not fully incorporated into forecasts of water utilisation.

Erosion and sedimentation

Extreme rainfall induces not only floods, but extensive episodes of erosion as well. As Fig. 5 indicates, rainfall-initiated land sliding is common throughout much of New Zealand. This form of erosion has been extensive in the past but may decrease in significance as the landscape relaxes from the major deforestation episode (see Crozier & Preston 1999). Nevertheless, New Zealand rivers carry high volumes of sediments generated as a result of erosion (Fig. 6), discharging over 1% of global sediment yield from a country that occupies only ~0.2% of the world's landmass. This illustrates clearly the high incidence of rainfall-related erosion, and disasters such as overbank deposition and associated damage to infrastructure are not uncommon. High erosion-related sediment yields are driven by both natural processes (e.g., Cropp River in Westland, Fig. 6) and those heavily influenced by anthropogenic alteration of the landscape (e.g., Waipaoa and Waiapu Rivers on the East Cape of the North Island, Fig. 6). The extent to which sediment disasters are linked to the multiple interests of communities and industry can only be understood at catchment scales. It is at this scale that magnitude-frequency relationships established between hillslope erosion process and downstream sediment yield can provide the template for targeted mitigation strategies (Trustrum et al. 1999).

Sediment disasters impact directly (and indirectly) on the economy. It has been estimated that the total annual cost of damages is $\$US_{2002}$ 52 million, with a further $\$US_{2002}$ 12 million spent on mitigation of soil erosion and delivery of sediments to streams (Krausse et al. 2001). There are also downstream implications in terms of water quality. In fact, water quality is a topical issue in New Zealand, with implications for human consumption, recreation, in-stream biota, commercial and recreational fisheries, and hydroelectric generation.

Sustainability of the water resource

Given the huge difference between the high value of the water resource to the New Zealand economy and the small amount of money spent on remediation and disaster mitigation, it is perti-

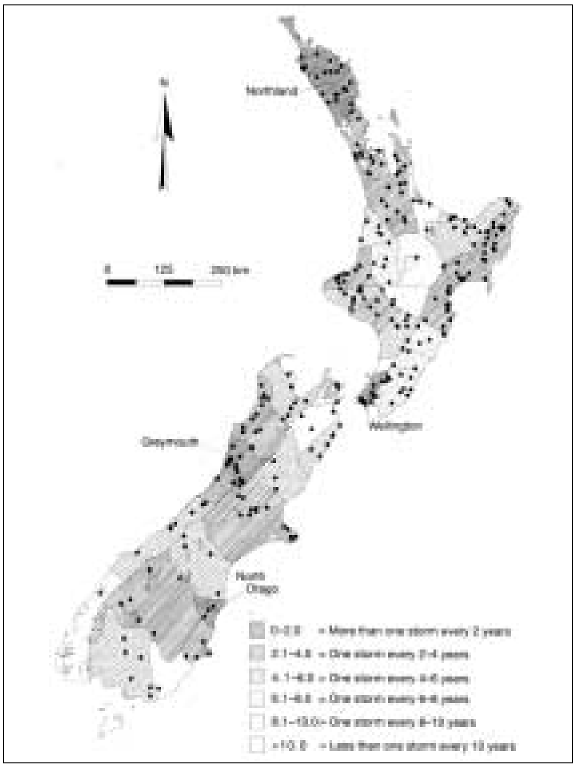

Fig. 5 Recorded incidents of landslide generating rainfall, 1870-1955 (Source: Glade 1998).

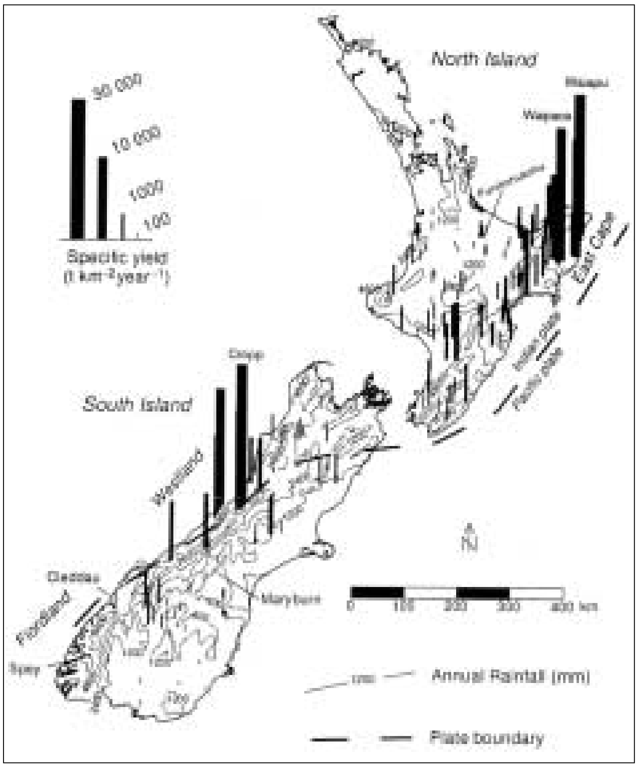

Fig. 6 Suspended sediment yields and mean annual rainfall isohyets. Sediment yield is proportional to bar size (Source : Hicks *et al.* 1996).

nent to ask whether enough is being done to protect the intrinsic water resource. To address this question it will be necessary to identify the cost of depletion of the resource in terms of the loss of soil water storage capacity, degraded water quality, and greater variability in the flow regime. With ever increasing demands on water resources - e.g., global consumption of fresh water is doubling every 20 years (Vidal 2002) - strategies to sustain the resource will need to be rapidly implemented.

How is agro-environmental education addressing these issues?

At a secondary education level, issues of hydrology and water resource use are potentially addressed within three subject areas: Geography, and, to a lesser extent, Science and Social Studies (J. Lynex, pers. comm.). However, Geography is not a compulsory subject, while Social Studies and Science are compulsory only for the first 2 years of secondary education (i.e. until Year 10). Within the Science curriculum, students may focus on various components of the hydrological cycle, although it appears that study of the cycle itself is not addressed (Ministry of Education 1993). Natural hazards are included, but teaching will generally focus on more spectacular phenomena such as volcanoes and earthquakes. For this reason, awareness of flooding is probably greater than that of drought.

In Geography natural hazards are specifically addressed in Year 11, the concept of sustainability is introduced by Year 12, and in Year 13 the interaction between human and biophysical systems is addressed along with the topic of resource management legislation (Ministry of Education 1990). At a national level, annually 35-40% of students will study Geography to Year 13, and might reasonably be expected to have some awareness of issues of hazards and/or sustainability of resource use. However, application of these concepts specifically to water is not prescribed; it is very much at the discretion of individual schools. It is unlikely, therefore, that secondary education contributes significantly to awareness of flood/drought issues among the general population.

At university level aspects of water resource

Table 1. Numbers of tertiary-level students enrolled within broad subject areas as of July 2000. (Source : Prof. P.J.J. Kamp, New Zealand-France Cooperative Workshop, July 2002).

Field of Study	Number	Percentage
Business	55,452	21.54
Humanities	26,725	10.38
Education	25,268	9.82
Natural and Applied Sciences	**17,734**	**6.89**
Medicine & Health	16,092	6.25
Social Sciences	12,634	4.91
Engineering	9,827	3.82
Art & Music	9,835	3.82
Computing	9,300	3.61
Agriculture, Horticulture, Forestry, Fishery	7,300	2.84
Law	6,205	2.41
Sport & Recreation	5,171	2.01
Architecture & Town Planning	3,867	1.50
Mathematics	150	0.06
Other	51,838	20.14
Totals	**257,398**	**100.00**

use and natural hazard assessment are addressed by various departments (Geography, Geology, Earth Sciences, Environmental Studies, etc.), making it difficult to quantify the students involved. Professor Peter Kamp (University of Waikato) has compiled figures for the number of students enrolled within different courses of study at all tertiary institutions (Table 1). While issues of resource use and hazard mitigation can arise in other subject areas, the most relevant category is Natural and Applied Sciences. Less than 7% of all tertiary students are enrolled in courses in this category, and not all of these will actually consider the water resource.

Table 1. Numbers of tertiary-level students enrolled within broad subject areas as of July 2000. (Source : Prof. P.J.J. Kamp, New Zealand-France Cooperative Workshop, July 2002).

Notwithstanding a relatively low level of attention given to these issues within formal education, the general awareness of water issues within the New Zealand community is high because of the dependence on water and the frequency of hydrological disasters. At community level, a wide range of efforts is being made to improve both awareness and understanding. The Ministry of Civil Defence has produced an awareness and practical advice leaflet for floods. Legislation relating to flood protection has been in existence since the 1940s, and comprehensive resource management legislation was enacted in 1991. Management of New Zealand's environmental resource is based on river catchments as the fundamental unit of organisation, and the regional and district councils responsible for this management use a range of approaches including community participation groups, education and awareness campaigns, a range of financial incentives and subsidies, and regulation. In addition, there are a number of non-governmental organisations and trusts that facilitate community participation in restoration programmes.

Extensive work has been done in the last half century both in quantifying the resource and its variability, and in designing protection works. More recently, attention is moving towards a more integrated understanding of catchment dynamics and their behaviour through time. New research programmes integrate land and water environments to assess land-use effects on sediment and carbon fluxes from river basins to oceans, and the potential role they play in addressing global greenhouse gas and climate change issues (Trustrum *et al*. 2002).

Summary

Although water resources (and related disasters) are fundamental to New Zealand's social and economic wellbeing, questions can be raised with regard to their sustainability given the potential for depletion over the longer term. Furthermore, the degree to which formal education focuses on these issues is minimal with few tertiary students studying environmental processes and their impacts. Although general public awareness is fickle and only becomes heightened following extreme storms and droughts, management of water resources and their impacts is embodied in resource management law and is implemented by national and regional organisations with increasing levels of community participation.

References

Crozier, M.J. & Preston, N.J. 1999. Modelling changes in terrain resistance as a component of landform evolution in unstable hill country. In Hergarten, S. & Neugebauer, H.J. (eds.) *Process Modelling and Landform Evolution*. Lecture Notes in Earth Sciences. Springer, Heidelberg. 267-284.

Duncan, M.J. 1992. Flow regimes of New Zealand rivers. In Mosley, M.P. (ed.) *Waters of New Zealand*. New Zealand Hydrological Society, Wellington. 13-27.

Glade, T. 1998. Establishing the frequency and magnitude of landslide-triggering rainstorm events in New Zealand. *Environmental Geology* 35 (2-3), 160-174.

Harmsworth, G., Barclay-Kerr, K. & Reedy, T. 2002. Maori sustainable development in the 21st century : the importance of Maori values, strategic planning and information systems. *Journal of Maori and Pacific Development* 3(2), 40-69.

Hicks, D.M., Hill, J. & Shankar, U. 1996. Variation of suspended sediment yields around New Zealand : the relative importance of rainfall and geology. In Walling, D.E. & Webb, B.W. (eds.) *Erosion and Sediment Yield : Global and Regional Perspectives*. IAHS Publ. No. 236. 149-156.

Krausse, M., Eastwood, C. & Alexander, R.R. 2001. Muddied Waters : Estimating the National Economic Cost of Soil Erosion and Sedimentation in New Zealand. Landcare Research NZ Ltd, Lincoln. 47 pp.

Ministry of Education 1990. *Syllabus for Schools. Geography Forms 5-7*. Learning Media Ltd, Wellington.

Ministry of Education 1993. *Science in the New Zealand Curriculum*. Learning Media Ltd, Wellington.

Mosley, M.P. & Pearson, C.P. 1997. Introduction : hydrological extremes and climate in New Zealand. In Mosley, M.P. & Pearson, C.P. (eds.) *Floods and Droughts : the New Zealand Experience*. New Zealand Hydrological Society, Wellington. 1-14.

New Zealand Meteorological Service 1985. Climatic Map Series, Part 6, Annual Rainfall. Misc. Publ. 175, New Zealand Meteorological Service, Wellington.

Page, M.J. & Trustrum, N.A. 1999. Landscape transformation since 1900. In Thorn, B. (ed.) *Geographica : The Complete Illustrated Reference to New Zealand and the World*. David Bateman, Auckland. pp. 82-83.

Page, M.J. & Trustrum, N.A. 2000. High resolution lake sediments from New Zealand - a record of late Holocene storm history, vegetation change and landscape response. *PAGES Newsletter* 8 (3), 17-18.

Patterson, M. & Cole, A. 1999. Assessing the value of New Zealand's Biodiversity. School of Resource and Environmental Planning, Massey University. 88 pp.

Tomlinson, A.L. 1992. Precipitation and the atmosphere. In Mosley, M.P. (eds.) *Waters of New Zealand*. New Zealand Hydrological Society, Wellington. 63-74.

Trustrum, N.A. & De Rose, R.C. 1988. Soil depth-age relationship of landslides on deforested hillslopes, Taranaki, New Zealand. *Geomorphology* 1, 143-160.

Trustrum, N.A., Gomez, B., Page, M.J., Reid, L.M. & Hicks, D.M. 1999. Sediment production, storage and output : the relative role of large magnitude events in steepland catchments. *Zeitschrift für Geomorphologie* Suppl. 115, 71-86.

Trustrum, N.A., Tate, K.R., Page, M.J., Sidorchuk, A. & Baisden, W.T. 2002. Towards a national assessment of erosion-related soil carbon losses in New Zealand. In Yuren, J. (ed.) *Sustainable Utilization of Global Soil and Water Resources*. Proceedings of the 12th ISCO Conference, Beijing. Vol. 3. 182-186.

Vidal, J. 2002. Blue gold : Earth's liquid asset. *Earth* (The Guardian), August. 6-8.

Waugh, J., Freestone, H. & Lew, D. 1997. Historic floods and droughts in New Zealand. In Mosley, M.P. & Pearson, C.P. (eds.) *Floods and Droughts : the New Zealand Experience*. New Zealand Hydrological Society, Wellington. 29-50.

NEW ZEALAND : DISCUSSION

Question : Can you clarify further on the concept and meaning of changing of water holding capacity during a century of NZ anthropogenic disruptions?

Answer : As the mean hill slope soil depth is reduced as a result of the expansion of landslide scans that progressively strip the soil mantles to bedrock the effect is to decrease soil water holding capacities on hill slopes, which makes soils more susceptible to either saturation than their forest antecedents. Run- off is therefore more likely to be delivered as overland flow than as through flow. A consequence of this is a long-term change in the run-off regime, with greater frequency of extreme high and low flows.

Question : Is the breakdown of hill slopes into < 28° ; 28-42° ; >42° common or is standard use in NZ? Do you use it also?

Answer : The breakdown of hill slopes to <28°, 20 -32, 32-42 and >42° is based on a significant number of hill slope measurements. For example, little landslide erosion occurs below 28° from 28-32° there is significant land sliding especially on hill slopes converted from forest to pasture. Little erosion occurs on this slope groups under forest. Above 32° erosion can be more significant under forest (natural erosion) and it is on these same hill slopes that rapid adjustment of hill slope soil depths occur after deforestation and conversion to pasture.

Question : Could you mention about the main disaster among the water related disasters in more details including the countermeasures being adopted in New Zealand?

Answer : More details are provided in my paper pages 6,7 & 8. I agree that countermeasures have only been covered in a generic form but NZ does have an extensive network of flood control schemes on all populated floodplains. On hill slopes block planting of whole tributary catchments by radiata pine is the most effective method of stabilizing hill slopes erosion although not necessarily the best for biodiversity or to maintain traditional farming infrastructures. On pasture slopes space planting of gullies and hill slopes by willows and poplar trees has been a standard countermeasure with varying degrees of success.

Question : Reducing the water holding capacity of the soil, is there any relation with the deforestation technique? Because if you use machinery, the soil becomes compact and the infiltration capacity becomes less considering, not only sealing and crushing.

Answer : Yes studies (Phillips et al) have shown that machinery does compact soils (on slopes below 25° where machines are used) and hence cause more sheet and rill erosion but does not affect land sliding significantly. Soil compaction certainly reduces water-holding capacity.

Question : For the time being the NZ has no problem regarding the water resources (ex. NZ has a large amount of freshwater). What will be your country's anticipation related to global climate change?

Answer : The temporal or spatial distribution of rainfall does cause problems of water allocation especially in the dryer east coast "rain shadow" regions. A change in global climate change is predicted to cause more extremes of floods, sediment disasters and droughts.

Question : What specific human activities are involved in anthropogenic erosion?

Answer : Includes all human activities that might affect erosion rates.

Question : What is the estimated range of anthropogenic erosion in New Zealand in tons/ha/yr?

Answer : Large range but in general anthropogenic erosion rates are on order of magnitude greater for landscapes converted from forest to pasture. In the highly erosion prone east coast tertiary soft rock geologies average sediment yields for the river basin are 6,750 tons/km^2/yr-1 which is high by global standards.

Question : What kind of soil and rock on the mountainous area can cause serious erosion in your country?

Answer : Steep mountainous areas are comprised of "older" pre-cretaceous rocks (including greywache's and granites etc.). The "softer" younger rocks, which flank both the eastern and western sides of the axial ranges, are comprised of tertiary sandstones, siltstones and mudstones that have all been rapidly uplifted from their respective sedimentary basins. These "soft" rocks are very susceptible to erosion.