RESOURCE MANAGEMENT ACT AND ENVIRONMENTAL RESEARCH
PERSPECTIVES OF THE USE OF SOIL-PLANT SYSTEMS TO MANAGE THE ENVIRONMENT[1]

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Abstract

From the regional councils' perspective the Resource Management Act (RMA) provides greater regulatory control over water quality and quantity management. Air and soil quality management is based on contaminant discharges. The regional councils can also manage land for the purpose of soil conservation. Despite the relative significance to water management, soil-plant systems continue to play a major role in environmental management in New Zealand.

Coupled with cultural needs and relatively higher assimilative capacity, soil-plant systems have led to land being the preferred discharge medium over water. Despite their relatively limited treatment capacity, constructed wetlands are also preferred over direct discharges to water. Market access for food products, climatic and soil conditions, land value and sensitive groundwater aquifers are important limiting factors.

Soil-plant systems are also vital in mitigating against non-point source discharges. Riparian strips are known to minimise terrestrial contaminant entry to surface water. A more important role of riparian strips is reducing water temperatures and thus minimising algal proliferation in nutrient enriched surface waters. Regional councils also promote the use of riparian trees to improve stream/river bank stability.

Regional councils have limited control over land use. However, councils can regulate land use for the purpose of soil conservation and water management. Trees and grass cover continue to contribute significantly in minimising soil erosion. Nevertheless, in areas where water recharge is critical to maintain water quantity, restrictions may be imposed on forestation to reduce water losses. In some regions, land use restrictions may be placed in sensitive catchments where water quality is the major focus.

There has been an increase in the use of soil-plant systems to remedy contaminated sites and rehabilitate mining sites. Whilst rehabilitation of mining sites has been in practice for a long time, phyto-remediation of contaminated sites is relatively new. Where there is migration of contaminants at a contaminated site, management/ownership requires resource consent. In their decision-making process, councils will consider the actual and potential risks of a contaminated site and the timeframe within which the contaminant migration is contained or minimised. Where off-site migration is to be dealt with urgently, phyto-remediation has limited use. Such technologies will be useful for long-term clean-up operations.

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[1] In: *Environmental management using soil-plant systems.* (Eds L D Currie, R B Stewart and C W N Anderson). Occasional Report No. 16. Fertilizer and Lime Research Centre, Massey University, Palmerston North. pp 199-224.

There are sufficient opportunities for regional councils to conduct/commission their own research or support/rely on public funded research in New Zealand. Depending on the affordability and urgency of the information requirement, councils fund their own research. Some councils conduct collaborative projects with research organisations or fund post-graduate studies. The relative council fund input to scientific research is low compared to their ongoing state of the environment monitoring. A larger proportion of such monitoring is not related to soil-plant system monitoring.

1. Introduction

Despite the low human population, the intensity of resource use is high in New Zealand. Consequently, the pressure on air, water, soil and the coast has been increasing rapidly in the past several decades. For example, the total number of cows increased from nearly 2 million in 1975 to almost 3.7 million in 2002. An additional 5000 km^2 land area may have been converted into dairy pasture within the past two decades. Leaving water demand for irrigation aside, the estimated current national water demand for stock watering and farm dairy washing is 5.6 $m^3 s^{-1}$. The current estimated dairy excreta-nitrogen input to soil is 0.5 million t y^{-1}, excluding farm dairy effluent-nitrogen. The amount of methane discharged from cows is 0.3 million t y^{-1}.

The challenge for resource managers (i.e. regional councils) in New Zealand is to maintain where the environment is already in good condition and enhance where degradation has occurred. With increasing pressures on resources is it possible to practise this 'maintain and enhance' policy? The Resource Management Act (RMA), the major environmental legislation in New Zealand history enacted in 1991 holds the answers. Compared to many other international environmental legislations, RMA is unique in its approach to natural resource management. While it promotes sustainable management of natural resources, any adverse effects (including cumulative effects) arising from the use of natural resources could be avoided, remedied or mitigated.

Soil-plant systems are not only vital to sustain life on earth but could also play a significant role in managing the environment. Can the soil-plant systems be used to avoid, remedy and mitigate adverse effects on the environment? Does scientific research quality and pace in New Zealand quench the information thirst of resource managers? How do resource managers access research information on soil-plant systems? Does the RMA provide sufficient opportunities to exploit soil-plant systems as one of the valuable tools to manage the environment in New Zealand?

2. Environmental management - New Zealand way

There is a lack of understanding about environmental management process in New Zealand by researchers. Without basic knowledge of such a process, scientific research projects will be reactive, impractical, non-beneficial, costly and untimely. This section will describe briefly the New Zealand environmental management process.

2.1. Local government

Regional, district and city councils form local government. At central government level the Minister of Local Government administers local government issues with close liaison with Local Government New Zealand (LGNZ). There are 12 regional councils, 4 unitary authorities (district councils that have the functions and roles of regional councils) and 74 district councils that are empowered to implement the RMA. Councils' operational matters are set out in the Local Government Act. Every three years councils are elected by local citizens through local government election. While the constituents elect Mayors for district and city councils, the councillors elect Chairs for regional councils. District councils (or referred to as territorial local authorities) provide roads, parks, waste collection, water supply and regulate noise level, buildings, land use and hazardous substances management and use hence are service oriented. Regional councils cover larger areas (with the exception of unitary authorities) than district councils and in general regulate the use of natural resources, including the coast. Most regional councils also provide passenger transport (buses) and participate actively in regional transport issues. Councils derive their main income from general and special rates, investments (e.g. ports) and administrative charges.

2.2. Regional councils – functions and powers

Environmental management related functions of regional councils are set out in s30 of the RMA. According to the RMA every regional council must produce a *Regional Policy Statement* that addresses significant resource management issues of the region. Such a statement has a life span of 10 years with objectives, policies, methods and environmental results anticipated to address regional environmental issues. On the other hand, the *Regional Plans* are not mandatory but are developed to address specific issues related to water, air, land or coast. They contain rules prescribing activities requiring resource consents (i.e. controlled or discretionary activities) or not requiring a resource consent (i.e. permitted activity) or banned activities (i.e. prohibited activity). When preparing *Regional Policy Statement* and *Regional Plans*, alternatives, benefits and costs of objectives, policies, rules and methods should be assessed; the process must involve public participation (consultation, submissions and public hearing); and decisions by councils can be challenged at the Environment Court before the policies or plans become operative.

Activities requiring consents will be either publicly notified or processed by the Council without notification and with written approvals from affected parties. If notified, any person can make a submission against or for the proposal. Submissions will be publicly heard by an independent hearing panel. Decisions by the panel can be appealed by any submitter or the applicant at the Environment Court. Costs related to the consent process should be paid to the Council by the applicant.

According to s35(1) of the RMA, to carry out their functions under the RMA effectively regional councils should also gather information and undertake or commission research. Since regional councils were formed by amalgamating the previous catchment boards in 1989 most councils have inherited a substantial amount of long term information on water. However, in terms of information on air, soil and coast, the councils rely on either scientific research or their own monitoring that has been performed since mid 1990s. In general, information collection involves one-off monitoring or long-term monitoring of the state of the environment and emerging or existing pressures on the environment. Funding for such monitoring is derived from general rates. Information gathered from compliance monitoring would also be integrated to understand the pressure on the environment.

Regional councils can take legal action against any person causing adverse effects on the environment or breaching regional rules or RMA. Councils could authorise enforcement officers to enter properties (except a dwelling house) to inspect and obtain samples of water, air, soil or organic matter. Minor offences could be dealt with by infringement notices served with a fine of up to $1000. Major or ongoing offences are taken to the Environment Court through prosecution or enforcement orders. Penalties for offences under the RMA will be up to two years' imprisonment or a fine not exceeding $200,000 and if the offence continues a further $10,000 per day during which the offence continues.

Every year councils produce an Annual Plan and invite the public to have input in the process. Annual Plans comprise the coming year's projects, targets and budget. At the end of the financial year councils will report their performance through Annual Reports.

2.3. Ministry for the Environment

The Minister for the Environment is responsible for the national policy statement. The Minister also has the residual powers to intervene when councils do not perform their functions and duties. In addition to the information collected by regional councils, the Ministry can also conduct monitoring and investigation on any significant environmental matter. It can also develop appropriate national environmental standards for noise, contaminants, water quality, level or flow, air quality and soil quality in relation to the discharge of contaminants. If necessary the Ministry can also make grants and loans to any person to assist in achieving the purpose of the RMA.

3. Environmental issues in New Zealand

3.1. Fresh water

Unlike many other countries, New Zealand is fortunate in having a large amount of relatively good quality ground and surface water resources as a result of regular rainfall, snowfall and relatively lower ambient temperatures. However, high intensity of land and water use means lowland rivers and streams in New Zealand have elevated levels of faecal bacteria, sediments and nutrients. Typical contaminant sources are non-point sources from farm run-offs, farm effluent discharges, stock access to waterways, nitrate contaminated ground water, accelerated and natural soil erosion, urban run-offs, leakage from reticulated sewage systems and septic tanks, and point sources from sewage outfalls and industrial discharges.

In agricultural catchments and areas where poorly managed land treatment systems exist and high numbers of septic tanks are in use, shallow ground water aquifers have been contaminated with nitrate. In the majority of these areas the nitrate level exceeds the New Zealand drinking water standard of 11.3 mg NO_3-N L^{-1}. In some agricultural catchments shallow aquifers (<30 m depth) contain nitrate-N in excess of 30 mg L^{-1}. Many researchers and resource managers use nitrate drinking water standard as 'pollute-up-to-level'. This approach is wrong in the context of surface water quality management because nitrate contaminated ground water could have significant impacts on surface water. In catchments where streams and rivers rely on ground water as a major source of baseflow, setting nitrate levels at 11.3 mg NO_3-N L^{-1} will result in nitrate elevated surface waters with high potential for algal blooms. This is because typically most streams and rivers are sensitive to nitrate levels > 1 mg NO_3-N L^{-1}. Due to low rate of flushing and greater exposure to sunlight, lakes are more vulnerable to lower nutrient enrichment than rivers and streams. Nutrient levels for lakes are monitored and reported in μg L^{-1} rather than mg L^{-1}.

Rivers and streams that are impounded with in-stream dams for hydropower generation, aesthetic or water take purposes are also sensitive to relatively small levels of nutrients. Impounded water creates artificial lakes and the management of these lakes should be similar to natural lakes. Rivers draining agricultural catchments such as Waikato River has elevated levels of nutrients and the presence of dams further accentuates algal proliferation. Structures in waterways also affect fish passage. While in the North Island structures affect trout fish passage, in the South Island (e.g. Otago) structures have arguably helped retain several unique New Zealand native fish species.

Apart from nitrogen, phosphorus (P) being one of the nutrients can also affect water quality. Ground water is generally not affected by phosphorus because of high capacity of phosphorus adsorption of New Zealand soil that prevents leaching of P. Major sources of surface water P are runoff of phosphatic fertilisers and effluent discharges to surface water.

Assimilation capacity of a waterway is a key factor in contaminant level in water. Where the flow of water is naturally at low levels (small streams), discharge of contaminant to waterways will cause significant adverse effects. With increasing water demand for community water, farm water supply and irrigation, water abstractions further reduce the assimilative capacity of a waterway. In parts of Waikato, Hawkes Bay, Tasman, Marlborough, Canterbury and Otago, water demand for agricultural and viticultural land uses is high, hence water allocation for water take purposes has been either fully or over-allocated.

Water temperature is a key factor influencing nuisance algal growth in polluted waterways. Elevated levels of nutrients may not be an issue where water temperature is not sufficient to cause algal proliferation. Recent outbreaks of toxic algae in New Zealand freshwaters are caused by synergistic effects of elevated nutrient and water temperature levels. Presence of algae with high water temperature can also increase water pH. Elevated water temperature combined with high pH levels can increase ammonia (NH_3) levels and hence fish toxicity.. Elevated water temperature is caused by absence of adequate shading for streams and rivers, high water abstraction, damming of water and global warming.

3.2. Soil

Soil contamination may occur from point or non-point sources. Past timber processing activities have resulted in many sites with elevated levels of copper, chromium, arsenic, boron and pentachlorophenol (PCP). Equally, the past use of persistent pesticides has also resulted in contaminated sheep dip sites, DDT contaminated pastoral farms and market gardening soils with high residual pesticide levels. In several cases the ground water and surface water have been contaminated by contaminant migration from soils. Regular applications of phosphatic fertilisers derived from rock phosphates with high heavy metals (e.g. cadmium) have also resulted in elevated levels of heavy metals in agricultural soils.

Continuous cultivation of soils for cropping or market gardening purposes has resulted in soil organic carbon depletion. Typically such soils have low nitrogen immobilisation capacity and high potential for nitrate leaching. These factors coupled with heavy nitrogen fertiliser use have resulted in ground water aquifers beneath cropping and market gardening soils with elevated levels of nitrate.

Poor soil cover management and riparian management, land disturbance including cultivation, mining activities, and natural land instability have resulted in soil loss. Soil loss is a serious long-term issue for lowland waters, harbours, estuaries, and the economy.

3.3. Air

In New Zealand the key air contaminants are particulates (including dust) (measured and referred to as PM_{10} – particles less than 10 microns), carbon monoxide, carbon dioxide, sulphur dioxide, nitrous oxide, nitric oxide and methane. Since methane, nitrous oxide and carbon dioxide are classified as greenhouse gases any reduction achieved in their emission is beneficial nationally and globally. Particulate matters are in elevated levels in urban areas with high industrial and traffic activities and where solid fuels are used for domestic heating. For example, during winter major cities such as Christchurch and rural towns such as Alexandra often exceed the national guideline for PM_{10} of 50 $\mu g\ m^{-3}$. Nuisance odour issues are also critical in rural and urban areas. Most regional councils receive and manage a large number of complaints related to odour. Conflicting land use zoning by district councils, reverse sensitivity, community expectation of an odour free environment, and ongoing rural and urban sources of odour are key factors driving odour complaints.

3.4 Coastal

New Zealand has a beautiful and large coastline. Due to intensive terrestrial activities (agricultural and point discharges) several beaches, harbours and estuaries have been affected by elevated faecal bacteria. Harbours and estuaries have also been affected by silt accumulation. Increasing demand for coastal spaces (subdivisions, marine farming, and structures) has resulted in loss of natural character. Increasing sea levels, coastal disturbances and insufficient or inappropriate coastal protection have contributed to coastal erosion.

4. Regional councils' use of soil-plant systems to manage the environment - Does the RMA promote the use of soil-plant systems to manage the environment?

4.1 Purpose and principles of the RMA and the use of soil-plant systems

The purpose of the Act is to promote sustainable management of natural and physical resources. Sustainable management includes the options of the use, development and protection of natural resources. These options could be used in a way or at a rate which enables communities to provide for their social, economic and cultural well-being, health and safety. With the ultimate aims of sustaining the potential of natural resources to meet the reasonably foreseeable needs of future generations and safeguarding the life-supporting capacity of air, water, soil and ecosystems, the RMA indirectly demands information on the state of the environment and the ways of avoiding, remedying and mitigating adverse effects.

According to the RMA adverse effects include cumulative (past and present) and potential (future) effects on the environment. By drawing a scenario of discharge to land that enters ground water, 'avoid', 'remedy' and 'mitigate' principles could be explained. 'Avoid' simply means no discharge to ground water (or no discharge to land that may enter ground water). 'Remedy' (in the dictionary context 'cure') means clean-up the aquifer from contaminants once the discharge has occurred. Using 'mitigate' in the dictionary context of 'alleviate' or 'reduce severity' could mean (a) sufficient land area is provided, (b) sufficient assimilation available in the aquifer, (c) pre-treatment of discharge to reduce contaminant level, and (d) provide opportunity for natural reduction of contaminant by for example plant uptake of contaminant from land. In the RMA context in addition to the above, 'mitigate' also means causing positive effects to 'compensate' for other or same adverse effects such as (e) planting indigenous vegetation to improve native habitat, (f) improving riparian management to reduce surface water temperature, (g) providing alternative water supply for those that are dependent on ground water in the area, and (h) any financial contribution.

It must be noted that the principles of 'remedy' and 'mitigate' do not apply to s6 and s107 of the RMA and any prohibited activities in the regional plans. S6 of the RMA requires protection of natural character of coast, wetlands, rivers, lakes, outstanding natural features of landscapes, areas with significant indigenous vegetation and significant habitats of indigenous fauna. S107 prescribes that a discharge to land (which may enter water) and discharge to water should not be allowed if the following effects occur in the receiving waters after reasonable mixing: "…*(c) The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials: (d) Any conspicuous change in colour or visual clarity: (e) Any emission of objectionable odour: (f) The rendering of fresh water unsuitable for consumption by farm animals: (g) Any significant adverse effects on aquatic life…"*

In short the purpose of the Act provides endless opportunities to use soil-plant systems to manage the environment by way of remedying and mitigation. Such opportunities will be discussed in detail in the proceeding sections in this paper.

4.2 Functions of Regional Councils related to the use of soil-plant systems
There are specific functions of the Act in s30(1) of the Act that demand the use of soil-plant systems.

"…(b) The preparation of objectives and policies in relation to any actual or potential effects of the use, development, or protection of land which are of regional significance:

(c) The control of the use of land for the purpose of-
(i) Soil conservation:
(ii) The maintenance and enhancement of the quality of water in water bodies and coastal water:
(iii) The maintenance of the quantity of water in water bodies and coastal water:
(iv) The avoidance or mitigation of natural hazards:
(v) The prevention or mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances:

(d) In respect of any coastal marine area in the region, the control (in conjunction with the Minister of Conservation) of-
(i) Land and associated natural and physical resources
(v) Any actual or potential effects of the use, development or protection of land, including the avoidance or mitigation of natural hazards…"

"…(f) The control of discharges of contaminants into or onto land, air, or water and discharges of water into water:

(g) In relation to any bed of a water body, the control of the introduction or planting of any plant in, on, or under that land, for the purpose of-
(i) Soil conservation:
(ii) The maintenance and enhancement of the quality of water in that water body:
(iii) The maintenance of the quantity of water in that water body:
(iv) The avoidance and mitigation of natural hazards:…"

According to the above functions a regional council could regulate the use of land or riparian planting for the purposes listed under s30(1)(c) or (g) respectively by providing for this in the regional plans, or by providing non-regulatory mechanisms to achieve the outcomes. Several councils have produced regional land plans and others promote non-regulatory mechanisms such as environmental education and incentives.

4.2.1. Actual or potential effects of the use, development or protection of land which are of regional significance
S30(1)(b) requires preparation of objectives and policies in relation to the above. Interpretation of this function is important since it could be confused with s6(b) of the Act, *"…recognise and provide for the protection of outstanding natural features and landscapes from inappropriate subdivision, use and development…"*. Whilst s6(b) is indirectly related to this specific function, s30(1)(b) requires preparation of objectives and policies in relation to any actual or potential *effects* of the use, development or protection of land *which* are of

regional significance. *Effects* could be adverse (negative), positive, actual or potential. A majority of the councils have not yet identified in detail the positive or negative *effects* of the use, development and protection of land, which are of regional significance. Most councils have only progressed as far as recognising regional issues in their Regional Policy Statements and by providing regular socio-economic information on their region. In most cases a detailed inventory of outstanding natural features and landscape of national importance has not been developed to fulfil s6(b) requirement. Since s6 is related to matters of national importance, the Ministry for the Environment is better positioned to provide the leadership. It appears that there is no such strategy forthcoming from the Ministry.

If a proper assessment of positive, negative, potential and actual effects of regional significance of the use, development and protection of land is performed, soil-plant systems will play a key role in such an assessment. Examples are indigenous vegetation's role in maintaining native habitat, impacts of soil erosion, benefits of high class soils, commercial crops or plants including clover-based pasture that assist/sustain a regional economy, and negative or positive effects of forestry, subdivisions and agricultural land use.

4.2.2. Soil conservation

Soil conservation as in s30(1)(c)(i) requires maintenance of good vegetative cover and choice of appropriate land use for the climatic and geological conditions. Soil erosion has been well recognised in New Zealand and attempts have been made at regional and farm level to minimise soil loss. Maintaining or improving soil fertility, particularly soil phosphorus levels, has been promoted in hill countries to sustain pasture production and minimise soil erosion. Many farmers have voluntarily retired pasture in unproductive or high slope areas for planting forest. Soil conservation as in s30(1)(g)(i) requires protection of lake, river and stream margins from erosion by fencing and planting with appropriate vegetative cover. Such measures had been undertaken well before the RMA was enacted through encouragement and subsidies from catchment boards. Nevertheless, soil erosion continues to be one of the significant issues for many regions requiring more work through regulatory and non-regulatory mechanisms.

4.2.3. Water quality

As for s30(1)(c)(ii) of controlling land use for the purpose of maintaining or enhancing water quality, a regional council could ban certain activities that significantly impact water quality of water bodies particularly outstanding water bodies in New Zealand. The debate of dairy conversion in Lake Taupo catchment continues where evidence is available on the adverse impacts of nitrate entry into Lake Taupo resulting in declining water clarity. The local regional council (Environment Waikato) has been working with the dairy industry and local farmers to discourage dairy conversions in the catchment. Since such action will only result in partial outcome, Environment Waikato is considering a variation to its Regional Plan. MfE is also interested in the outcome and hence involved with Environment Waikato in assessing options on possible rules to manage land to minimise nitrate entry into Lake Taupo. Replacing a number of existing livestock farms with a preferred soil-plant system such as forestry could be the long term solution which will reduce ongoing nitrate entry to lake. It must be noted that there is nothing environmentally unfriendly about pastoral cover as a soil-plant system. In deed, it is grazing, cultivation and heavy nitrogen fertilisation of pasture that cause nitrate leaching. Because of relative control over nitrate leaching in 'cut and carry' systems in contrast to a grazed system, 'cut and carry' systems or grain-fed systems (as in Europe) may be considered for situations similar to Lake Taupo water quality management. Due to constraints with market access, effluent management and cost benefit, it is impracticable to promote ‘cut and carry’ systems with ‘barn-managed’ ruminants in New Zealand.

4.2.4. Water quantity

S30(1)(c)(iii) of the Act requires regional councils to control land use for the purpose of maintaining the quantity of water bodies. In catchments where demand for consumptive use, farming, irrigation, hydro-power generation and industrial use is high, regional councils control the take, damming, diversion and use of water through the consents process. This will allow water to be available for the purposes of recreation and aquatic habitat. In almost all regions except for the West Coast, water is in high demand. Under the circumstances, regional councils have to collect and manage water budget information to sustain surface water flows and aquifers in the region. Increasingly information on soil-plant systems is becoming one of the key factors in managing water resources in New Zealand.

In water-short catchments forestation is considered as having a significant impact on water availability. This is because forests are known to intercept a substantial amount of rainfall that would have otherwise recharged an aquifer or increased surface water flow. A case law exists in New Zealand where forestry activity was disallowed by Tasman District Council (a unitary authority) to minimise impacts on water availability. This decision was supported by the Environment Court when appealed by the forestry company. This illustrates the significance of soil-plant systems' influence on water quantity management in New Zealand.

4.2.5. Prevention or mitigation of natural hazards

Natural hazards can occur through flooding, drought, tsunami, earthquake, volcanic activity and cyclones. Most frequent natural hazards occur in New Zealand through flooding and drought. S30(1)(c)(iv) of the Act requires control of land use for the purpose of avoiding or mitigating natural hazards. S30(1)(g)(iv) also requires control of riparian planting for the purpose of avoiding or mitigating natural hazards. Most regional councils have been active in controlling flooding effects and have been undertaking bank protection work through planting trees (or removing inappropriate vegetation), construction of structures and management of gravel. Funding for such work is derived from general or special rates.

Although flooding effects appear to be visible, greater economical loss is sustained through prolonged and severe droughts in New Zealand. Apart from water take restrictions applied during times of drought, very little progress has been made by the majority of councils to mitigate the effects of drought.

4.2.6. Coastal protection

In relation to the coastal marine area S30(1)(d)(v) of the Act requires any actual or potential effects of the use, development or protection of land, including the avoidance or mitigation of natural hazards. S30(1)(c)(ii) & (iii) of the Act also requires control of the use of land for the purpose of maintaining or enhancing coastal water quality and quantity.

As stated before, terrestrial activities have significant impacts on coastal marine areas, e.g. soil loss or erosion, farm and urban runoffs and industrial discharges. Rivers and streams convey such discharges as sediments, nutrients and faecal materials to New Zealand coastal areas including harbours and estuaries. In areas with high slope and intensive rainfall (e.g. Coromandel Peninsula), land use such as forestry contributes significantly to sediment accumulation in the harbours. In addition to these effects, rising sea levels and poor sand dune management in the coastal marine areas have resulted in coastal erosion.

Soil-plant systems have been vital in tackling land based contaminant discharges to the coast. As discussed before, good riparian management assists in reducing faecal and nutrient runoff to streams and prevents stock access to waterways. Increased use of land treatment (or effluent irrigation) systems to discharge farm, industrial and sewage effluent have also reduced the impacts on the coast. Several councils (e.g. Environment Waikato and Bay of Plenty) also regulate land use practices such as forestry harvest to minimise sediment accumulation in the coastal marine area. Under such circumstances, soil-plant systems are manipulated or used through patch harvesting of forestry, providing slash as mulch and maintenance of appropriate riparian strips.

Plants have also been vital in providing stability to beach sand. Several councils actively promote coastal protection by involving local communities (e.g. Beachcare groups) to establish and maintain appropriate vegetative cover for sand dunes.

4.2.7. Discharges to land

S30(1)(f) of the Act requires regional councils to control discharges to land, air and water. This is an obvious and key provision in the context of environmental management and hence since the enactment of the RMA in 1991 there has been a significant focus on this by regional councils. Most discharges in New Zealand would require resource consents. Most regional councils have permitted the following activities:

- Fertiliser application to land
- Pesticide use
- Farm effluent irrigation
- Burning certain materials, including solid fuel for domestic heating and vegetation
- Storm, drainage, cooling, drinking, swimming pool, bore drilling and testing water discharges to land and water
- Emissions from small industries and vehicles to air
- Septic tank discharges to land
- Certain solid waste discharges to land
- Non-toxic tracer dye discharges to water

4.2.7.1. Permitted activity discharges

Agri-chemicals

When permitting discharges such as fertiliser and pesticide or any agri-chemical discharges, regional councils have required the use of certified materials and the use of an industry code of practice. There is an ongoing debate on controlling nitrogen fertiliser application to land in light of nitrate contamination. Typically in New Zealand most aquifers under market gardening and dairying have high nitrate levels (Close *et al.*, 2001). Several New Zealand studies show that heavy fertiliser-N application causes nitrate contamination in ground water in market gardening and dairying areas (Selvarajah et al., 1994; Ledgard *et al.*, 1996).

The major cause for nitrate leaching in dairying is attributed to N leaching from urine patches from cows. Nevertheless, heavy N fertiliser application can accentuate N leaching in dairy pasture (Ledgard *et al.*, 1996). This is because most well established dairy pasture systems that are typically high in organic-N (>6 t ha^{-1}) and low in C:N are unable to accumulate additional N as organic-N. While the fertiliser industry limits N loading to 200 kg N ha^{-1} y^{-1} pastures (NZFMRA, 1998), there are dairy farms that use fertiliser-N in excess of 400 kg N ha^{-1} y^{-1}. Several farms use in excess of 1 t N ha^{-1} y^{-1}. Relatively cheap fertiliser-N availability combined with high demand for dairy product export has resulted in ad hoc and heavy use of fertiliser-N in New Zealand.

Dairy industry (majority representation by Fonterra Co-operative Group Ltd) currently focuses on water quality issues and is in the process of establishing regional specific accords with regional councils following the proposal of a national accord (Farmlink, 2002). In the proposed five targets to achieve improved water quality by 2012, adoption of nutrient budgeting by 2007 to minimise nutrient losses to water is related to fertiliser use. At this stage there is no guideline available from Fonterra on the upper limits of fertiliser-N use. Currently, neither the fertiliser industry nor the dairy industry is actively discouraging excess fertiliser-N use in dairying. A majority of dairy farmers do comply with the fertiliser industry guidelines, however, about 10% (>1300 farms) of the dairy farmers apply fertiliser-N at excessive rates. With increasing intensity of dairying more farmers are likely to use excessive rates. Fertiliser-N is an essential tool in sustaining milk production, however, it should be used strategically rather than a supplement to clover-N.

Clearly, the fertiliser permitted activity provisions are being breached by a number of dairy farmers according to the regional councils' current permitted activity provisions. It is ironic that while a soil-plant system has a major role in improving environmental quality, when managed poorly it can degrade the environmental quality. Very soon regional councils could develop regional rules that could prohibit excess use of fertiliser-N in New Zealand if neither industry actively controls high fertiliser-N application.

Septic tanks

Septic tank discharge to land has been allowed as a permitted activity provided certified systems are installed and the location is not in any ground water protection zone or close to a bore or waterway. While single septic tank discharges cause minor on-site effects, collectively they can decrease water quality and warrant the need for reticulated sewage discharge. Due to rapid population growth and increase in holiday homes in coastal and rural areas, almost every region is affected by cumulative effects of septic tanks in New Zealand. There is also a local community resistance to reticulated sewage systems because of the fear of further rural and coastal developments. Under such circumstances it is regional councils' role to monitor the pressure and state of the environment and report to their respective District Councils to take remedial actions such as providing reticulated sewage effluent facility.

It is unfortunate that the term ‘septic tank’ is still in use. In the past the only way of treating domestic sewage was by capturing solids in a tank and allowing overflow into subsoil. If the objective is to reduce nitrate leaching to ground water, obviously the old system is not effective because up to 80% of human excreta is in liquid-N form (i.e. urine). However, in the past decade there have been considerable changes to the design and operation of septic tanks, hence the appropriate term is ‘on-site sewage treatment system’. Many such systems still have a ‘tank’ to intercept solids, but are sophisticated in treating liquid wastewater to enhance nitrification and denitrification processes. Such systems have infiltration pipes to discharge treated effluent close to topsoil to encourage plant absorption of nutrients and evapo-transpiration losses and effectively reduce nitrate leaching potential. Increasingly such soil-plant systems are being used to minimise nitrate leaching in on-site sewage treatment systems.

Farm effluent

Of all permitted discharges farm effluent irrigation has attracted a considerable amount of wider interest and input to the regulations from community, farmers, researchers and regulators (regional councils and Ministry for the Environment), and environmental groups including statutory bodies such as Fish and Game Council and Department of Conservation. In 1989, an investigation by Hickey *et al*. (1989) confirmed that despite using two pond systems, the treated farm dairy effluent was of very poor quality requiring many folds dilution in the receiving waters to assimilate contaminants. Later a three year study on effluent pond performance on 15 systems in the Waikato also concluded with similar findings (Selvarajah, 1996a). With the current cow number of 3.7 million, the estimated annual discharge of effluent to waterways would be 50 million m^3. Even after being treated by a standard two-pond system, such a discharge would result in an annual input of 10,000 t N to New Zealand waters. Soon after the enactment of the RMA the cow number was 2.5 million, hence the annual N input from treated farm dairy effluent to waterways would have been 7500 t y^{-1}. In the early 1990s, with a sense of urgency, several regional councils attempted to provide transitional provisions for farm effluent discharges while developing specific regional plans. For many councils it was obvious the only pragmatic and effective way of avoiding discharges to water was to use soil-plant systems such as grazed pasture as a treatment system. Consequently, as a first step many councils prohibited raw effluent discharges to surface waterways. As a second step farm effluent application to land was made a permitted activity to discourage treated effluent discharges to waterways.

While there was a common sense approach to encouraging soil-plant system as a treatment system, the major setback to such an approach was the lack of information on environmentally sustainable effluent loading rates. When the RMA was enacted, researchers and regional councils did not know the effluent-N and hydraulic loading of effluent. This lack of information was one of the major setbacks for many regional councils in introducing permitted activity rules to allow non-consented discharges of farm effluent to soil-plant systems such as pasture. In early 1990s several councils approached crown research scientists to obtain such information and were told insufficient information was available on effluent-N loading rates and more research was required. There was a general frustration that science could not deliver such basic information despite the past 6-7 decades of intensive and extensive work on N transformation processes in pastoral systems.

Environment Waikato was the first council to propose a rule in 1994 with a technically justified effluent loading of 150 kg N ha^{-1} y^{-1} for grazed pasture after considerable desktop research. The desktop study used relevant national and international research on N transformation in pasture with a focus on effluent-N based on N budget (Selvarajah, 1996b). The loading rate resulted in a considerable amount of debate among the regional councils and researchers on its technical rigour and application to a wide range of climatic and soil conditions. Some councils were desperate to use results from one-off lysimeter studies on ‘cut and carry’ effluent irrigation trials and justified 200 kg N ha^{-1} y^{-1} as the effluent-N loading rate. Others promoted 300-400 kg N ha^{-1}as an annual farm effluent loading rate. Several councils continued to require resource consent for farm dairy effluent irrigation. In light of high dairy conversions in 1998 Southland Regional Council (Environment Southland) commissioned an independent investigation on effluent loading rates and received a recommendation of 150 kg N ha^{-1} y^{-1} as a suitable loading rate. Since 1994 there has been a considerable amount of effluent irrigation research in New Zealand. To date 150 kg N ha^{-1} y^{-1} remains a widely used farm effluent loading rate in New Zealand (e.g. Waikato, Otago, Southland, Hawkes Bay regions and parts of Auckland Region). In ground water protection zones Otago Regional Council requires resource consents for effluent irrigation to apply effluent at the rate of 75 kg N ha^{-1} y^{-1}.

While there was an initial reluctance due to fear of the effluent-N loading rate regulation being the precursor for regulating fertiliser loading, gradually, use of soil-plant systems to treat farm effluent was accepted by the farming community in New Zealand. For example in 1994 in the Waikato, of the 5,500 dairy farms 70% were discharging treated effluent to waterways. Currently, in the Waikato Region only 20% are discharging to waterways. Such trends apply to the majority of regions including Otago, Southland, Bay of Plenty and Auckland. With only 350 dairy farms in the region, Otago Regional Council is aiming to achieve zero treated farm effluent discharges to waterways. Many farmers are convinced that there have been benefits such as increased soil fertility and pasture growth from effluent irrigation. Despite this there has also been poor management of effluent-soil-plant systems resulting in effluent runoff to streams, which prompted legal actions (infringements and prosecutions) by regional councils against offending farmers.

Similar principles have been applied to other farm effluents such as poultry and piggery. Most councils have allowed piggery and poultry effluent application to soil-plant systems as a permitted activity. Some councils require consents for piggery effluent application to soil-plant systems because of nuisance odour emission issues.

4.2.7.2. Consented discharges

Industrial (e.g. meat works, dairy factories, wool scouring, vegetable processing), reticulated sewage or high volume sewage and certain farm effluent discharges require resource consents. The significance of soil-plant system in treating high strength and high volume effluent was well recognised in New Zealand pre-RMA. In order to minimise impacts on surface water, the predecessors of regional councils (i.e. catchment boards) authorised and promoted industrial effluent irrigation with no limitations to effluent loading. Consequently, some industries were allowed to apply effluent-N in excess of 1 tonne ha^{-1} y^{-1}, resulting in severe ground water nitrate pollution (Selvarajah *et al*., 1994). Since the enactment of the RMA, the regional councils have been facing the issue of effluent loading rate during the process of such consent applications. There has been an opportunity to grant short-term ‘by trial’ or long-term consents with environmental review clauses by imposing ground water quality monitoring conditions. However, councils were concerned about setting N loading limits that might result in ground water contamination.

Despite the lack of information on effluent-N loading rates to soil-plant systems, based on either past research or anecdotal evidence, the soil-plant system has been considered by the wider community as superior to any other treatment or disposal systems. It has been common knowledge that compared to aquatic systems, soil-plant systems are able to receive and assimilate effluent with high levels of BOD or dissolved organic carbon, faecal bacteria, P and ammonia (NH_3). An aquatically toxic contaminant such as NH_3 is not considered as toxic in soil-plant systems because of the high buffer capacity of soils. With the relatively low amount of sandy soils in New Zealand combined with high adsorption of P, there is little or no danger of effluent-P leaching to ground water and reaching surface waters. In the Waikato Region there is a site where as a result of industrial effluent applications Olsen-P in soils rose to 400 mg kg^{-1} soil, nevertheless, this did not result in P leaching to ground water.

According to the RMA it is vital that regional councils consider the interest of Maori (or iwi) when managing natural or physical resources. From a spiritual viewpoint, in order to preserve the ‘Mauri’ (spiritual life force) of water, iwi discourage direct discharges of effluent, particularly sewage, to surface water. Historically iwi relied on soil-plant systems, particularly soil, to treat human excreta. Maori did not have any access to scientific information on the effectiveness of soil in filtering and treating harmful pathogens and other contaminants but perhaps relied on their observations and experience of risks associated with not using soil systems (or mother earth) to treat harmful substances. There is an increasing pressure from iwi on regional councils to avoid sewage discharges to water. In some cases iwi begin to accept indirect discharges through trenches or constructed wetlands.

For the above reasons, computerised, modern and sophisticated treatment systems engineered to remove BOD, P and N from urban sewage treatment plants are unable to match the efficiency of a well managed effluent-soil-plant system. Unlike many European nations, land is plentiful in New Zealand, hence soil-plant systems still remain as superior treatment systems. Currently, industries, waste managers (generally District Councils) and regional councils are collectively taking advantage of the multi-treatment capacity of soil-plant systems in New Zealand. The existing scientific information on sustainable loading of sewage and industrial effluent is sparse. Under such circumstances regional councils continue to rely on desktop studies (e.g. Selvarajah, 1996b), or information obtained from long-term monitoring of consented discharge sites. There are several well monitored sites available in New Zealand (e.g. Hautapu, Buxton Farm and Lichfield dairy factory effluent irrigation sites and Rotorua municipal effluent irrigation to forest). Such sites provide more information in understanding the long-term effluent treatment capability of soil-plant systems than New Zealand science has delivered.

Pasture

Unlike non-consented farm effluent-N loading rates, the consented industrial or sewage effluent-N loading is typically high. For example, consented effluent-N loading to grazed pasture is double the amount (300 kg N ha^{-1} y^{-1}) of permitted farm effluent-N loading. As stated before, consented sites are monitored intensively for ground water contamination, hence higher loading rates are justifiable. In contrast, the only monitoring undertaken on a permitted activity of effluent irrigation is of a compliance nature, which is a visual assessment of ponding or surface runoff of effluent and land area available for irrigation.

It is well known that pasture uptake of soil-N is relatively high (on average 500-600 kg N ha^{-1} y^{-1}) compared to many other plants on earth. Therefore if used as a ‘cut and carry’ system, pasture offers a high uptake of N resulting in the use of a relatively small land area. Unlike in Europe, New Zealand farmers continue to rely on grazed pasture therefore the use of ‘cut and carry’ system is limited to hay and silage paddocks. With low availability of other ‘cut and carry’ systems, effluent is increasingly applied to grazed pastures in New Zealand. As stated before, grazed dairy pastures have a high potential to leach nitrate because of grazing animal excreta deposition (on average 450 kg N ha^{-1} y^{-1}). Consequently, effluent-N applied to grazed pasture systems is in addition to animal excreta-N from grazing animals, which further increases the potential for nitrate leaching. Therefore, use of grazed pasture as a soil-plant system to treat effluent will not be effective. Regional councils allow farm effluent irrigation grazed pasture without resource consents because only up to 10% of the effective grazing area on any farm is used for farm dairy effluent irrigation. Therefore on a catchment scale, risk of N leaching from farm dairy irrigation is minor.

Although the high N loading issue could be overcome by using ‘cut and carry’ system, there are emerging issues that limit the use of pasture as an effluent treatment system. For example, the once praised, well managed and successful Taupo township pasture irrigation site is unfortunately a present failure. It was successful from the viewpoint of cleaning up and reducing faecal and nutrient input to the headwaters of the Waikato River. This was the first large-scale (136 ha) ‘cut and carry’ pasture system in New Zealand. Grass was harvested and distributed free to dairy farmers as hay – a well accepted concept of waste recycling by environmentalists. Nevertheless, recently dairy industry has discouraged the use of grass produced from sewage effluent irrigation as animal feed based on global market access issues. The guarantee of zero presence of human pathogens in the distributed hay would not be sufficient to satisfy the industry concern that is purely based on consumer perception. Other livestock industries have not yet restricted the use of sewage irrigated grass hence there is an opportunity to use sheep and beef farms to utilise the grass produced from the Taupo site in the meantime until restrictions are placed on it.

Forestry

The existing trend indicates that in the near future sewage and meat processing effluent may not be irrigated to any food-producing crops including pasture in New Zealand. This means a soil-plant system such as forestry provides certainty, hence appeals as a better land treatment system. Currently a number of forestry sites exist in New Zealand to treat sewage effluent or sludge (e.g. Rotorua, Whitianga, Whangamata, Christchurch). Again, the success of forestry sites relies on effluent-N loading rates. Sites receiving high N loading have resulted in nitrate contamination of ground water and streams (e.g. Whangamata).

Long-term monitoring of forestry effluent treatment systems indicates that, unlike pasture, pine trees have a limited uptake of N (i.e. 100 kg N ha^{-1} y^{-1}). This means that to treat sewage or meat wastewater a larger land area is required. Most existing forest treatment systems have been designed by using large land parcels already established with forest for commercial harvest in mind. In the absence of already existing forests, converting existing pastoral land to forest is costly. However, for small rural townships such an option is still attractive. For large urban areas (e.g. Hamilton) where there is no known large exotic forest nearby, acquiring pastoral land is extremely costly. In the case of Hamilton, assuming a daily effluent volume output of 40,000 m^3 with 30 mg L^{-1} of total-N level, the land area required to use pine forest for effluent irrigation would be more than 4000 ha at an N loading rate of 100 kg ha^{-1} y^{-1}. The estimated cost of such a land parcel in the Hamilton area would be in excess of $NZ80 million.

Despite effluent-N loading limitations, forest systems will continue to be an attractive effluent treatment system in New Zealand. This is because (a) unlike pasture greater hydraulic loading including high winter loading can be applied to forest systems because of their ability to intercept rainfall; (b) no frequent harvesting of crop – harvesting of trees would take more than 25 years unless for coppice purpose; (c) risk of spray drift is minimal; and (d) no additional N input (e.g. grazing animals excreta input adding further complexity and contamination risks).

Other crops

Whey, being a by-product of milk process, has high N, P and dissolved organic-C. Application of whey to pasture has to be performed carefully to avoid overloading and pasture death. Application of whey is a consented activity, however, generally resource consent is granted without a need for public hearing. Increasingly whey is being applied to maize in New Zealand. Maize is used as cattle feed and requires a high input of nutrients. Since whey has high BOD it is applied to cultivated soils before planting maize.

It is clear that pasture and forestry systems are widely promoted to treat effluent in New Zealand. Apart from constructed wetlands, it is very rare that other soil-plant systems are used to treat effluent. Scientists have failed to fully exploit soil-plant systems to treat effluent. A majority of research to date has focused only on pasture and forestry. Any future and successful research on soil-plant systems to treat effluent should provide for quadruple bottom lines (i.e. social (public acceptance), economical (financial benefit), environmental and cultural). With an emerging energy crisis, the New Zealand government is very much interested in alternative energy sources. There is an opportunity to consider soil-plant-effluent treatment systems that could provide bio-fuel. Such research may require a collaborative approach from soil and industrial scientists.

Constructed wetlands

Constructed wetlands are artificially constructed to simulate the environment of natural wetlands. Natural wetlands are known to filter contaminants. It is a general practice in New Zealand that natural wetlands are not used for the disposal of effluent. Most natural wetlands are recognised for their high ecological values and increasingly they are being protected from point and non-point sources of pollution. Many natural wetlands are also a source of food for iwi hence effluent discharges to such wetlands are prohibited. However, as stated before, iwi promote the use of constructed wetlands to further treat effluent before it is discharged to waterways. This is because they believe the earth (or soil) which is part of the constructed wetland system will be able to cleanse any unwanted contaminants or unspiritual materials.

There has been a considerable amount of research in New Zealand on the effectiveness of constructed wetlands in treating effluent. Most of these studies are short-term and it is not clear about the long-term sustainability of such systems. Generally, constructed wetlands are used as a tertiary treatment system. Such systems have plants that tolerate saturated and anaerobic conditions. Plant uptake of nutrients is very low, therefore the purpose of the wetland plants is to contribute organic-C and oxygen in the rhizomes or pockets of rhizosphere. In theory, when NH_4^+-N enters such pockets it is nitrified and subsequently denitrified. Some constructed wetlands also encourage subsurface flow to promote oxygenation and nitrification. However, in the long-term they have limited capacity to treat P, NH_4^+-N and suspended solids because of chemically saturating and physically clogging the system. Lack of oxygen in the systems results in little or no nitrification of NH_4^+-N. Shallow water depth and exposure to UV encourage pathogen die-off. However, because of wildlife input such systems could result in elevated faecal bacteria. In certain cases wetlands are used to remove heavy metals from effluent. Wetland sediment with adsorbed heavy metals is periodically removed and replaced with new sediment material. Nevertheless, since the disadvantages (a. uncertainty of long-term treatment efficiency, b. poor treatment of P and NH_4^+-N, and high strength and high volume effluent, c. no financial benefit to the end user, d. high initial cost, and e. little or no control of hydraulic loading due to rainfall input) outweigh the benefits, these systems are not widely used in New Zealand.

Contaminated sites

Past practices of use of persistent, toxic chemicals combined with poor management of chemicals has resulted in soil contamination at many timber treatment, landfill and gas-work sites in New Zealand. These chemicals are pentachlorophenols (PCPs), copper-chromium-arsenic (CCA), pentachlorobiphenyls (PCB), boron and hydrocarbons associated with petroleum products. Currently, PCPs and PCBs have been de-registered in New Zealand along with persistent agric-chemicals (e.g. DDT) including the use of sheep-dips (persistent organophosphates) which had caused soil contamination on many farms. In several cases the above contaminants had begun to migrate to ground water and surface water. Such a situation is ironic since soil-plant systems are being used as an effective system to treat many contaminants, however, most soil-plant systems are unable treat heavy metals and persistent chemicals.

Currently regional councils have identified the majority of such sites and maintain a register. They also regularly report to the district councils the details of these sites for the district councils to maintain PIMs (Project information Memorandum) and LIMs (Land Information Memorandum). Property buyers can access contaminated sites information. Where there is potential or actual migration of contaminants into air, water or adjacent land, regional councils would require the current site owners to obtain discharge consents. Consents would require on-going monitoring and treating or avoiding contaminant migration.

In the case of agricultural soils contaminated with persistent pesticides (non-point pollution), diluting contaminant levels in soil by ploughing is a practical option. Where the extent of contamination is high, ploughing will not be a suitable solution. Studies have been initiated in New Zealand to use plants to decontaminate sites with extensive contamination. This process is referred to as phytoremediation. The principle behind this approach is containment, absorption and dilution of contaminant.

While phytoremediation is promising, the application is limited to certain contaminants and sites. Currently HortResearch (New Zealand) is conducting several field and laboratory trials that are useful in understanding the use of soil-plant systems to decontaminate or reduce contaminant migration. These studies indicate that soil-plant systems are effective in gradually decontaminating the sites coupled with their ability to reduce hydraulic loading that drives leaching or contaminant migration. Provided the end use of plants used for decontamination is carefully planned and managed (e.g. plants used in decontaminating boron contaminated soils could be used on agricultural/horticultural soils that are deficient in boron), the studies are promising in dealing with several contaminated sites in New Zealand. Nevertheless, the use of soil-plant systems may not be a practical option for sites that have an ongoing high rate of contaminant migration and require an urgent treatment process to stop/minimise contaminant migration. In short, it must be emphasised that once soil-plant systems are contaminated with persistent chemicals, the treatment options could be laborious and costly. Therefore while soil-plant systems offer a wide range of treatment options to treat non-persistent contaminants, resource managers should be aware of their limitations to treat persistent chemicals. Effluent or bio-solids containing heavy metals should be pre-treated before irrigated or disposed of onto soil-plant systems. Under such circumstances a one-off application may be possible. The use of existing guideline values as ‘pollute up to’ levels is not advisable since further refinement of understanding the fate and breakdown of persistent chemicals could result in more stringent guidelines which would render such sites as contaminated.

Rehabilitation of waste soil

Along with fertile soils, plenty of water resources, large access to sea, good quality air and stunning scenic views, New Zealand also has valuable minerals, solid fuels and metals. Licence to mine or quarry (aggregate production) these precious non-renewable resources is provided by the government (Ministry of Commerce). Once a company has secured a licence, it may require resource consents to mine/quarry and manage arising discharges. Mining is either open-cast or underground. In New Zealand, the majority of mining is open-cast. Mining activities result in millions of tonnes of waste soil from tailings or mining itself. Tailing soils may contain certain chemicals such as arsenic or cyanide and require containment or treatment. On the other hand, waste soils and rocks (spoils) resulting in mining activities require stabilisation to avoid sediment runoff and landscaping to provide natural character or revenue (pastoral or forestry). Generally most mining activities require consents from regional and district councils and landscaping issues are dealt with by district councils. It is a regional council role to ensure contaminant containment (including sediment) or treatment.

Quarrying is minor form of mining and while small quantities of quarrying are allowed through permitted activities, the majority of quarrying requires resource consents from regional councils to discharge dust and disturb land and district councils consents to deal with noise, transport and preservation of natural character. Since no toxic contaminants are released from quarrying, the issues are related to dust emissions and sediment runoff. If improperly managed quarry sites could become breeding grounds for mosquito or other pests.

Mining sites require long-term and follow-up monitoring by the regional and district councils. If the mining company is not proactive, landscaping and contaminant containment issues may be overlooked. Generally sufficient bonds are required to undertake mining activities, hence until the consent authority is satisfied with the completion of work, bond money is not released to the consent holder.

Rehabilitation of mining requires planning (end land use, drainage, consideration of local climatic conditions, usefulness of waste material, cost), landscaping (drainage, slope, erosion) and planting appropriate vegetation (pasture, exotic or native forest). Planning for end use should be made at the stage of mining itself to allow proper piling of soil waste, dredging and spoil. It should be aimed to provide a gentle slope to avoid high risk of erosion of rehabilitated sites. Alluvial mining generally results in a flat landscape. Lack of rainfall could be the most significant factor affecting rehabilitation. Another factor is topsoil; it could be costly if topsoil is to be imported. Inappropriate vegetation or land use selection could also lead to failure. While an initial focus on improving soil fertility to enhance vegetative cover establishment is important, long-term monitoring and management of soil fertility are equally vital to maintain vegetative cover.

The past two decades of trials in New Zealand (Massey University and Landcare Research) have led to effective use of soil-plant systems to manage the adverse effects of mining (e.g. Central Otago, Coromandel). It is well known which factors will contribute to a successful rehabilitation. The major limiting factor in New Zealand is low emphasis on enforcement by regional and district councils to require mining companies to provide effective long-term rehabilitation. In general, either consent conditions are not sufficient to require effective rehabilitation or little or no monitoring is performed to ensure good rehabilitation. As a result there are sites that are infested with weeds or prone to erosion. Mining companies with good practice are able to make substantial efforts to leave mined sites that would provide long-term viable land use.

4.2.8. Riparian management

Riparian margin management has been considered as a panacea for water quality issues in New Zealand. The benefits of the riparian management were realised well before the enactment of the RMA (dating back to 1970s) and there were schemes to subsidise the establishments of riparian strips with Land Information Agreements between the funders (catchment boards) and the land owners. To date several councils have continued such funding by providing riparian plant supply or finance for riparian management (e.g. Taranaki and Waikato). Several councils have also started promoting Landcare Groups to recognise water quality issues in their catchments and work collectively (e.g. Waikato, Otago).

The RMA also recognises the importance of the riparian management, hence provided a specific function for regional councils that promotes soil-plant systems in riparian margins to maintain or enhance water quality of a water body. Section 30(1)(g) of the RMA requires regional councils to control planting in or around the bed of a water body for the purpose of soil conservation, maintenance and enhancement of water quality, maintenance of water quantity, and avoidance or mitigation of natural hazards.

The anticipated outcomes by regional councils from good riparian management are:

- Reduce contaminant surface run-off, particularly phosphorus, suspended solids and faecal matters.
- Avoid stock access to water, resulting in nil direct faecal input to waterways and reduced bank erosion.
- Reduce ground water nitrate entry into surface water through denitrification.
- Reduce water temperature by providing shade which alleviates nuisance algal growth and improves fish habitat.
- Provide improved habitat for macroinvertebrates and fish by contributing substrates.

There is sufficient evidence available to suggest that if properly designed and managed (i.e. appropriate choice and maintenance of vegetative cover, width of strips taking slope as a major factor, fence type, appropriate pest control in the strip), riparian margins can achieve all the outcomes anticipated by regional councils except for reducing nitrate entry to surface water. Uptake of nitrate by riparian plants is relatively insignificant compared to the total nitrate entry to surface water. Generally limiting factors for effective denitrification are short ground water residence duration, high ground water flow rate and cold riparian temperature, which outweigh the conducive factors such as organic carbon supply and saturated soil conditions.

Often, preventing stock access to waterways is interpreted as providing a riparian margin. In many cases, preventing stock access to waterways could be achieved by erecting and maintaining electric fences. This will avoid bank erosion and direct excreta input to waterways. Such a process does not involve planting trees along the surface water margins. Providing a riparian margin requires careful planning including knowing the desired outcome. This is because in most cases riparian margins are planted with trees, fenced permanently and, depending on the slope, productive land has to be sacrificed to provide sufficient width. On small streams and rivers, permanent riparian strips with trees will have significant positive effects by minimising water temperature rise. This will improve habitat quality and reduce nuisance algal proliferation. In short, the significance of soil-plant systems in riparian management is well known by researchers, resource managers and wider community.

5. Research on the use of soil-plant systems to manage the environment

Research into soil-plant systems in New Zealand dates back to the 19^{th} century. However, the main focus on soil-plant research was to increase/improve food, timber or fibre production. For example, past dairy pastoral research focused on high dry matter and milk solids yield. Fertiliser input, irrigation and grazing management was studied intensively and extensively to obtain optimum yields. Little or no regard was given by researchers to land use impacts on the environment. While there were few initiatives to minimising applied fertiliser losses in the 1980s which indirectly benefited the environment, the real focus on environmental research related to soil-plant systems only started in the early 1990s.

Unlike soil-plant system research, fortunately, the environmental research on water quality was carried out more intensively in the 1970s. Previous water catchment boards and government research organisations such as DSIR (Department of Scientific and Industrial Research) were responsible for ground water and surface water quality (physical and chemical) monitoring and research. This was driven mainly by the interest in water use and human health safety and hence such bodies were funded or responsible to carry out such work. In the 1980s water research/monitoring also started to pay attention to adverse effects on aquatic ecology.

The early 1990s is the most critical period for environmental research history on soil-plant systems in New Zealand. There were two significant changes in New Zealand: a major restructuring of government research agencies, and the enactment of the RMA in 1991. A new research funding structure called PGSF (Public Good Science Funding) was initiated by the government, which would enable any researcher in New Zealand to bid for research funding. If viewed superficially, it may appear that the introduction of the RMA, the subsequent environmental awareness, and information needs had been the major factors in increased environmental research on soil-plant systems. However, the truth is that the new PGSF structure had more significant positive effects on environmental research into soil-plant systems than did the introduction of the RMA. PGSF recognised and provided significant funding for environmental research and the researchers had to use every possible funding output to access to perform scientific research. The new structure encouraged government research organisations to be administered as if they were private, which resulted in aggressive and innovative ways of obtaining research funding. The funding structure ensured there was industry based (pastoral) or theme based (water and atmospheric) funding. However, the environmental output of the funding provided more research opportunities in new areas such as use of soil-plant systems to manage the environment.

In short, unfortunately New Zealand soil scientists have spent much of their 120 years of research on improving primary production in New Zealand without any regard to adverse effects on the environment or using soil-plant systems to mitigate adverse effects. Fortunately, certain aspects of the past production-based research by soil scientists will contribute to understanding soil-plant systems to better manage the environment. The past water quality monitoring and research also assisted in highlighting impacts of intensive agriculture on water quality.

5.1. Vision and strategy

As a multi-million dollar industry, the research organisations in New Zealand lack in strategic and tactical directions and visions. Although this has improved lately, despite the increased and expensive corporate body presence at almost all research organisations, research planning on environmental matters appears to be reactive and piecemeal. It is known that scientists in general are weak in strategic or tactical planning nationally and globally. Where research funding is plentiful, scientists are not motivated to focus on planning, e.g. Australia, USA. In New Zealand modern scientists are expected to be multi-skilled. It may be argued that scientists are best at full time research and engaging them into other tasks (i.e. planning, bidding, technology transfer) is not an efficient use of their time. Under the current funding regime New Zealand scientists can not provide their undivided attention to quality research. For successful survival and performance New Zealand research organisations should either train their scientists to be multi-skilled or maintain a team of scientists or ex-scientists or administrators who have strategic planning skills and are able to spend much of their time on research planning, bidding and technology transfer. As every scientist agrees, top scientists should be well recognised and rewarded for their expertise and need not undertake administrative tasks in order to earn higher salaries. Administrative roles are for people with appropriate skills and not suited for scientists who happen to be on high salary scales.

While securing funding is vital for research organisations, strategic planning and visions are not necessarily entirely income based. Proper planning on environmental research is outcome based rather than output based and aims to identify environmental issues and provide cost effective solutions. Sometimes well planned long-term research is required to provide effective solutions. Without the above characteristics environmental research will continue to be in reactive mode. Had the visions and the ability to strategise research focus and directions existed among our soil scientists to realise the unlimited opportunities soil-plant systems offered in solving many New Zealand environmental issues, at least in the 1970s, the current situation of adverse effects of intensive agriculture on the environment and the degree of environmental degradation would have been in a more easily manageable status.

5.2. Understand environmental issues

It is vital scientists understand environmental issues and pressures. Ironically, this itself requires environmental monitoring and intensive or extensive research. To date, lack of understanding of environmental issues has led to a piecemeal approach and ineffective solutions. Without understanding environmental issues, appropriate solutions will not be possible. Solutions to environmental issues are not always derived from further research. Most environmental issues require community education and awareness.

5.3. Applied science

While pure science is the foundation for any scientific research, successful environmental research applies pure science to understand and resolve issues. Applied science should provide cost effective, practical and technically defensible solutions. Methods used in applied research should preferably be field based and if laboratory based, they should simulate field conditions sufficiently.

5.4. Information dissemination

Research planning, conducting research, data collection, interpretation and synthesis and dissemination of information are basic processes of any research. Scientists should be hypothesis neutral and are expected to provide honest and technically defensible interpretation. Once the information is ready to be released, scientists have a responsibility to assess the consequences of the release of information. Because of a lack of knowledge, the wider community could be 'scare-mongered' by particular information. Certain information may be highly political, either locally or globally, and may tarnish the clean and green image of New Zealand. While it is expected that scientists be neutral of politics and issues, they should be responsible in managing information in the interest of the community and country. On the other extreme, unpublished or uninformed information is equally irresponsible. Scientists and their organisations have a responsibility for timely information dissemination to the end users and policy makers. Environmental scientists can fulfil their role only when their well researched information is put to good use by the community or policy makers to achieve the desired environmental outcomes.

5.5. Collaborative research

Collaborative research in New Zealand has been emphasised consistently since the restructuring of research agencies in New Zealand. This is to ensure value for the taxpayers' money, avoid duplication of research, and develop research teams with multi-skills and knowledge base. Compared to many developed countries duplication of environmental research is relatively low in New Zealand. For example in the US, ground water nitrate issue in any given state is studied by US Geological Survey (USGS), US Department of Agriculture (USDA), US Department of Ecology (USDE), US Department of Health (USDH) and US Environmental Protection Agency (USEPA). Sometimes there is also a state USEPA and federal or central USEPA performing separate studies. Under such a structure there is a possibility of a ground water bore site being sampled by all the above agencies at any given time. A similar scenario exists in Australia. It could be argued that this a healthy situation from the viewpoint of employment opportunities for scientists. However, with a small population base in New Zealand we can not afford the systems that exist in US or Australia and furthermore, it is not effective use of taxpayers' money.

It is widely believed by scientists from research organisations in New Zealand that collaboration is only required between each research organisation. It is important that environmental research also requires collaboration with regional councils because they perform a substantial amount of state of the environment monitoring. Many regional councils employ highly qualified scientists to perform environmental monitoring and reporting tasks. In many such cases, it may not be a practice for regional council scientists to publish environmental information in refereed national or international publications. This is because the information collected by the regional council scientists is for the councils to manage regional natural resources effectively and hence producing council reports is generally sufficient to serve the purpose.

The scientific community believes that the number of publications in refereed journals is one of the measures of professional scientists' success. It often considers 'scientists' with little or no refereed publications as 'pseudo-scientists' regardless of their qualifications and experience. Consequently, information disseminated from a regional council is treated as 'regional council' information rather than scientific information. Many research agencies suspect the quality and integrity of the regional council information. During the seeking of funding or support from regional councils the general thrust is on gaining financial support rather than working together to use councils' skills and knowledge. Once financial support is gained there is no active participation gained from council scientists and when the project is completed a report is sent to Councils. There is also a perception that regional councils cannot/are unable to perform research. Indeed, s35(1) of the RMA states "…*Every local authority shall gather such information, and undertake or commission such research, as is necessary to carry out effectively its functions under this Act*…". Moreover, most councils have quality assurance programmes to ascertain quality data collection. Several councils are in the process of developing and managing meta-data systems (data on data management). Often technical reports are peer reviewed before being reported to the councils. If poor quality information is provided to the council there are political implications.

More recently, there have been several collaborative environmental research projects conducted collectively by regional council scientists and research organisations. Such synergy is vital to share strengths and information between regional councils and research organisations. Collaborative research requires mutual trust and respect. In contrast to the popular myth, collaborative research does not mean financial contribution from all parties involved. There may be contribution in kind such as information or equipment provision, field assistance and above all, knowledge and skills. A true collaborative research seeks the best experts to achieve its goals, is not limited by financial contribution, and involves active collaborative participation from the initial stages of project planning.

5.6. Advocacy, integrity and leadership

As stated earlier, the existing system of research funding has contributed to increased environmental research in New Zealand. While this is very positive, there are also negative aspects. Increased competition to survive and to increase business output has led scientists to actively seek consultancy work. This has resulted in conflicts of interest and behavioural changes in scientists (e.g. providing information to suit clients' needs, selective information provision that hides the truth) which have resulted in loss of integrity and credibility. It is preferable to avoid advocacy, however, if advocacy is essential to seek a desired environmental outcome for the country, the integrity of the information should not be tarnished. It is not easy to maintain scientists' passive role when issues such as global warming, genetic engineering, and high class soils are being debated. Such issues are of national importance and highly political and hence should be considered as corporate issues and tackled collectively rather than by individual scientists expressing their views in an ad hoc manner. Any views expressed or maintained by a research organisation should be in the interest of the nation. Each research organisation should stringently maintain and adhere to good practice ethics. Such approach will improve credibility and long-term financial benefits.

5.7. Is a backward move the way forward for environmental research?

It has been more than a decade since the restructuring of research organisations, the new science funding system and the enactment of the RMA. There have been sufficient opportunities to review the strengths and weaknesses of the research funding system. There has been some 'fine tuning' of the existing system by changing funding outputs and requiring stakeholder involvement in the research planning process. The existing system continues to demand scientists' research hours for administrative purposes and to require strategic or tactical planning.

If New Zealand is to lead in environmental research such a situation is not sustainable for the long term. The existing system will not be free of duplications, poor quality research, poor information dissemination, poor collaboration and above all brain drains. The way forward is to engage scientists in nationally and regionally important projects by drawing their undivided attention to scientific research and information dissemination. There should not be any need for bidding for funding. Environmental research projects should be planned at high levels, by local and central government representatives, based on their information needs. Long and short term projects should be contracted to research agencies and academic institutes depending on the pool of expertise needed. There may be a relatively small pool of funding for any researcher or research organisation that could access by bidding for specific projects.

5.8. Regional councils contribution to soil-plant systems research

As stated before, according to the RMA regional councils can either commission or perform their own research. Most regional councils monitor water quality and quantity regularly. This is partly because their predecessors were catchment boards whose major focus was water management and currently the RMA requires active regional council participation in water management. Land management focus is on soil conservation, contamination and riparian management. Generally, land management issues are not regulated and councils use incentives and voluntary mechanisms to achieve desired outcomes. Information related to land or land use (e.g. soil maps, topography, vegetative cover) is obtained from research organisations.

It must be emphasised that much of the water quality issues are caused by land management issues (e.g. nutrient leaching and runoff, faecal and sediment runoff, contaminant migration from contaminated sites, stock access to water). It is well acknowledged that in New Zealand >70% of the surface water contamination is caused by non-point sources, most of which have land origin. While mitigation measures such as riparian management can either 'mask' the effects of nutrient enrichment of surface water or minimise contaminant runoff, the problems have to be dealt with at the source. Good knowledge of the source (i.e. impacts of poor land management) is important to tackle the issues at the source rather than seeking 'Band-Aid' solutions and 'ambulance-at-the-bottom-of-the-cliff' approaches. Soil scientists have knowledge to provide practical solutions, yet, they are neither recruited nor used by most councils to provide information on sustainable land management. The ongoing use of hydrologists and hydro-geologists would continue to place most councils in reactive mode to challenging water quality issues. In the absence of soil science expertise, contaminant generation from soil would be treated as a 'black-box process' by most councils. Hydro-geologists who are best at tracking down nitrate plumes temporally and spatially are often puzzled by nitrate leaching processes in soils. Top waste water engineers continue to treat soil as ‘black-box’ and avoid soil-plant systems as one of the treatment options and continue to recommend treated effluent discharge to water for their district council clients. The closest such engineers get to using soil/earth is by using either trenches or rock filters to ‘dispose of’ treated effluent.

Although engaging soil scientists will assist in dealing with non-point pollution issues, the extent of nitrate pollution caused by non-point sources in New Zealand may exist for some time. This is because (a) soil scientists are currently in the process of ‘catching up’ with information gathering on nitrate leaching and contaminant treatment by soil-plant systems and (b) provided the solutions are delivered by soil scientists, control of land use by regulation (i.e. similar to the European approach) or by voluntary methods will require substantial time and effort to be effective. If councils continue to apply the pressure on point source polluters, surface water quality will continue to improve, not to a desirable quality, but to an extent non-point source pollution contributing >90% of the water pollution in New Zealand.

If information on soil-plant systems is required and if in-house expertise is not available, councils will commission or use a consultancy or research agency to gather information. Investigations are contracted through a tendering process or by preference for particular expertise. Investigations are also conducted through post-graduate studies. Provided post-graduate studies involve quality scientists as supervisors, they offer high returns for regional councils. Generally, such studies are initiated by either regional councils, academic institutes or research agencies. Councils allocate funding annually for information gathering through their annual plan process. Annual plans are produced for every financial year (1 July to 30 June) and funding information should be available before December for the following year's draft Annual Plan. Researchers requiring funding for the proceeding year should consult with the councils at least before November each year. Regional councils consider regulation (policy, consents and compliance) as their core function. Information gathering depends on needs and resource availability. Councils with a high income or large rate base collect considerable amounts of information. Other councils limit information gathering to their basic needs. When budget cuts are made by councils, such cuts affect information gathering more significantly than other core functions.

Since there is little or no information sharing between regional councils, there is a substantial amount of ‘re-inventing’ of environmental information. Similar situation applies to regulations. There will be significantly different approach to a given issue by any two bordering regional councils. In the past there have been attempts to co-ordinate research through SARCC (Science and Research Co-ordinating Committee) by regional councils and a collation on on-going projects and significant issues by MfE and regional councils (*Critical Issues Review, Resource Managers Group and MfE*). These attempts have not resulted in any improvement of the situation. Very rarely regional councils plan and assess information needs. If information needs are assessed, often prioritisation of information gathering is absent. In addition to regional councils' information, MfE also gathers a substantial amount of information either through commissioning its own research or through Sustainable Management Funding (SMF). Since there has been little or no consultation on information gathering by MfE, the information may not be useful for regional councils. If useful information is produced by MfE, it is rarely used by regional councils because the existing information dissemination mechanisms are not effective. The only way forward is for MfE to regularly collate regional council information gathering, and provide regular feedback to individual councils to avoid duplications and co-ordinate information gathering. Recently, MfE has consulted with regional councils to share information formally with regional councils. If administered properly by MfE, this process will help minimise duplication and improve information collection co-ordination.

6. Conclusions

Although it has long been realised by the wider community, it has taken more than a century for scientists to realise the significance of soil-plant systems in managing the environment in New Zealand. The RMA, relatively recent and significant New Zealand environmental legislation, provides unlimited opportunities to utilise soil-plant systems to improve environmental quality. In the past decade, due primarily to government research funding restructure and to a lesser extent the enactment of the RMA, environmental research has intensified in soil-plant systems. To date soil-plant systems have been successfully used in New Zealand, (a) to improve surface water quality, by reducing soil erosion and effluent discharges and by reducing nutrient, sediment, faecal runoff and water temperature through riparian management, (b) to reduce soil loss and prevent erosion, and (c) to rehabilitate 'waste' soil resulting from mining. Soil-plant systems also offer opportunities for the long-term treatment of contaminated sites with persistent organic chemicals and heavy metals.

Although research in soil-plant systems has intensified, it is fragmented and there is still a lack of research co-ordination, prioritisation, collaboration and funding to study major environmental issues and to provide solutions. Regional councils should use soil-plant expertise to understand and deal with non-point source pollution such as nitrate pollution. There is an expectation on environmental scientists to be multi-skilled to perform administrative tasks to gain funding for research. Consequently, increasingly top scientists either emigrate from New Zealand or are involved in full time administration for job satisfaction and financial benefits respectively. Being a small and one of the leading nations in environmental management, the strategic and tactical directions on environmental research should be at high level involving local and central government. Scientists should not be required to bid for funding for environmental research.

Disclaimer: The contents of the paper are not necessarily entirely based on the Otago Regional Council's or other regional councils' policies and the views are author's own.

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