Eroding or not eroding? Human activity, geomorphology and the sediment budget of Roberts Bank, Fraser River Delta, Canada

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Human activity can have implications for sediment budgets and influence our understanding of geomorphology. The effect of human activity on Roberts Bank, located on the southern margin of the Fraser River Delta, Canada, is an example. Two terminal facilities were constructed in the late 1950's-early 1960's near the delta crest of Roberts Bank with causeways linking to the mainland across the tidal flats. Both terminals have been expanded since then. The north-westerly terminal is a coal and container port serving Pacific Rim markets and the south-easterly terminal provides ferry services to Vancouver Island. Large-scale sedimentary bedforms occurring in water depths of 10 to 120 m were first documented in 1975. It has been suggested that these bedforms indicate the delta foreslope is eroding since no sediment sources for the bedforms other than the foreslope sediments themselves have been identified. If the foreslope is eroding, it puts the terminals at risk of being impacted by slope instabilities. This presentation will provide evidence from sediment budget and geomorphic analyses that the bedforms are related to terminal construction, the foreslope does not appear to be eroding and our understanding of human activity can influence our understanding of geomorphology.

Characterisation of process domains in glaciated headwater systems of coastal British Columbia

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Glaciated headwater systems are presently poorly understood. This study aims to partially fill such research gap by characterising active geomorphic process domains in selected basins of coastal British Columbia. The framework adopted integrates static, process and process-response landscape zonations in a sediment budget approach. Accordingly, three interdependent geomorphic aspects are considered. These are (i) the spatial distribution of dominant sediment sources (shallow rapid failures), (ii) the definition and delineation of geomorphologic process domains (i.e. hillslope and fluvial) and relative transition zone, and (iii) the identification of potential linkages between area-slope plots (process domains) and landslide magnitude-frequency relations.

It is anticipated that addressing the first and second research components will form a basis for the morphometric characterisation of the glaciated montane landscape of coastal British Columbia. This is an additional research goal that will be pursued and should allow explaining regional and sub-regional controls on the spatial distribution of sediment sources, the extension of process domains, and the shapes of landslide magnitude-frequency relations. Results are expected to improve our understanding of glaciated headwater systems, so that (i) a conceptual model for their functioning can be proposed, and (ii) sediment budgets for these portions of the landscape can be evaluated at different scales.

Geochemical denudation in alpine environments

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The last 50 years have seen increased recognition of the importance of geochemical processes in many alpine systems. In this paper, I treat solute dynamics in a geomorphic context on a variety of scales. Solute yields (on the order of 10 mm ka^{-1}) from large, high mountain drainage basins are usually lower than corresponding sediment yields (which may exceed 100 mm ka^{-1}). However, solute yields are still often greater than the global average, even in non-carbonate terrains. This level of geochemical activity is associated with characteristics common to high mountain environments: glacial areas; freshly-fractured rock debris; and high rates of water flux. Rates of solute yield from small drainage basins within mountain systems are even more highly variable and reflect contrasts in soil and bedrock materials; geomorphic history; glacierized areas; precipitation amounts, and landscape dynamics. Within such small basins, variability probably continues to increase, though there are relatively few studies which treat more than basin averages. In Green Lakes Valley, Colorado Front Range, yields of cations and Si derived from the basin materials decrease with increasing basin area and are closely correlated to water yields. However, we still need to identify better the sources from which the solutes are derived; the reaction rates in its generation, and the pathways through which it is transported to the basin outlet. These influences are presumed to reflect the local bedrock and soil structure; the location of geomorphically active sites within the basin, and the spatially variable contributions of “aggressive” water. In turn, these contrasts may have long-term significance for the development of the mountain landscape.

Spatial distribution of sediment sources in a mountainous and metamorphic basin, a case study of the Liwu River, eastern Taiwan

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The Liwu River Basin (621 km^2), characterized by very deep and narrow gorges, is located in the eastern flank of the Backbone Ridge of the Taiwan Island, outcropping with various metamorphosed rocks. Slope failures, also the major sediment sources, are not uncommon phenomena in this forestry basin due to its high relief, fractured bedrocks and frequent triggering forces, mainly typhoon rainfalls, earthquakes and sometimes human interferences. Based on the land cover surveys held in 1988 and 1998, this research examined the spatial distribution of the slope failures in relation to the stream/catchment order within this river basin.

These sites are widely distributed, but mainly located along the major divides in the west (slate-outcropping) in the Liwu basin. The area of the slope-failure sites of the first 11 (in 1988) or 13 (in 1998) 2^{nd}-order catchments is over half of the total figure, and they are also the most effective on sediment supply in the Liwu basin. Most of the slope-failure sites are either very close to 1^{st}-order streams or gullies. It implies the good coupling between slopes and channels and, with rather steep channel gradient, the effective transportation once sediments entering into the channels.

Estuarine energies and suspended sediment transport and distribution

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The Scheldt estuary (Belgium - the Netherlands) is characterised by a specific energy pattern resulting from the interaction of wave energy, tidal energy and river energy. Suspended sediment transport and distribution along the estuary is powered by and follows this energy distribution pattern. Observation of suspended sediment transport shows the existence of three estuarine turbidity maxima (ETM). It is a highly dynamic estuary subject to important anthropogenic activities, such as maintenance dredging of the shipping channel and harbours. The estuary has undergone major deepening modifications and dredging operations since the late 1960s. Fluvial-marine equilibrium of suspended sediment exhibits significant shift and indicates marine influence further landward. The characteristic of suspended sediment is induced by and is a function of e.g. tidal phase, spring-neap tide, longitudinal and vertical distribution mechanisms, flocculation, seasons, short- and long-term of anthropogenic influence and estuarine maintenance.

Year-to-year variability of solute flux in meltwaters draining from a highly-glacierised basin

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Electrical conductivity was monitored continuously in the Gornera, which drains the 83% glacierised basin of area 82 km^2 containing Gornergletscher, Pennine Alps, Switzerland, during summer months, in order to provide an indication of meltwater solute content during each of the four years 1979, 1983, 1987 and 1998. Discharge was also recorded between 1970 and 1999. Solute flux was calculated as the product of electrical conductivity and discharge, with hourly resolution, with a view to assessing the extent to which year-to-year variability of discharge influences solute transport. Total discharge of the Gornera between May and September was in the range –39.1% (1978) through +38.9% (1994) of the 1970-1999 period mean of 118.75 × 10^6 m^3. The range of variability of electrical conductivity was between –25.0% and +29.1% of the mean of 19.6 μS cm^{-1} for the months July through September in the four study years. Intra-annual range of total July through September solute flux in the Gornera extended from -22.4% (in 1987, the year in the four during which discharge for the three months was greatest) to +12.4% (in 1979 when discharge was the lowest) of the four study year mean, which represents an average cationic load of ~25 × 10^6 eq. Variability of total solute flux (c_v = 0.142) was greater than that of total discharge (c_v = 0.127) in the three month period over the four years. Considerable intra-annual variability of total discharge over the three decades suggests that annual totals of solute flux will also have fluctuated significantly from year to year.

A comparison of Little Ice Age lake sediment geochemical and dendro-geomorphological records from the upper Fraser River area of British Columbia

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This study assesses lake sediment and geochemical records and moraine chronologies in the upper Fraser River watershed, British Columbia, in order to resolve differences in interpretation and clarify sediment production and sediment delivery processes. Moose Lake (15.3 km^2; 1032 m a.s.l.) contains a partially varved record indicating variable but relatively constant rates of accumulation during the last millennium, despite the known occurrence of significant Little Ice Age glacial advances in the region. Forefield deposits in the headwaters of the basin (Reef Icefield) indicate that outlet glaciers recently extended up to 1.9 km down-valley from their current positions. Dendrochronological dating of these surfaces shows that phases of moraine construction occurred just prior to ca. 1751 A.D., 1840 A.D., 1856 A.D. and 1880 A.D. While not reflected in the lacustrine accumulation rates, increased sediment production attributable to glacial activity is evident in the geochemical composition of these sediments. Variations in Ca and related elements derived from glaciated carbonate terrain within the Moose River sub-basin (including Reef Icefield) indicate gradually increasing delivery from these sources from the 12^{th} though 20^{th} centuries. Peak yields occurring ca. 1200 A.D., 1500 A.D., 1750 A.D. and 1900 A.D. correspond closely to documented periods of increased glacial activity.

Sediment Budgets of Lowland Floodplain Sedimentation

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Understanding the sediment budgets of large, lowland rivers illuminates various aspects of their form and behavior, such as their planforms, rates of migration, and floodplain form. These budgets often reflect the interaction of fluid mechanics and sediment transport in the current hydroclimatic regime with crustal deformation and other slow, enduring, Earth processes. The small gradients are significantly perturbed by tectonic deformation of resistant materials beneath or along their valleys, causing changes to sediment transport capacities and channel migration. The effects of Quaternary sea-level changes propagated far inland, leaving a strong imprint on the modern budget of sediment transport and resulting alluvial landforms, and slow changes of land and sea level continue to affect the sediment balance and form of some river mouths. The scale of their channel and floodplain changes involves very large fluxes of sediment, and therefore the evidence of changes in their boundary conditions, such as sea level and sediment supply, persists for long periods of time. Hydrologic regimes along uncontrolled rivers force flow over bank for relatively long periods of time, and this regime combined with the typically fine sediment load of lowland rivers causes large amounts of overbank sedimentation. The combination of large amounts of overbank sedimentation with high channel shifting rates along many large rivers focuses attention on the interaction of channel and floodplain to explain the sediment budget of the valley.

The scale and complexity of these processes require the employment of various forms of monitoring from satellites, and the use of isotopes and hydrologic modeling, along with sediment sampling to understand the sediment budget of alluvial valleys. These concepts are illustrated with examples from the Amazon River basin in Bolivia and Brazil.

Sediment loads and sources in the Bush catchment: A move towards informed management strategies

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A decline in the survival of salmon from ova to smolt had been reported in the River Bush, Northern Ireland, due partly to habitat degradation. A monitoring programme was initiated in order to promote improved sediment management at the catchment scale. Bed and suspended sediment loads were quantified leading to the identification of specific grain types and transport events contributing to the sedimentation of salmon spawning redds. This presentation reports on supplementary work aimed at classifying the sources of these sediments in the catchment. A combination of visual observations, GIS "erosion potential" maps and bank erosion monitoring were used to assess large-scale sediment processes and guide more detailed study. Sediment fingerprinting techniques (Organic Content, PSA, XRD, XRF, Mineral Magnetics and Radionuclides) were then applied to elucidate the link between soil erosion and downstream sediment delivery. Information generated from sediment source ascription was transferred into a scientifically justified plan aimed at reducing fine sediment transport in the Bush catchment. Initially, management strategies applicable to the generic source problem were evaluated. Following this, detailed site feasibility studies (e.g. cost, likelihood of uptake, benefits) were incorporated. This work showed that effective catchment management has to be steered by detailed sediment budget information.

Asymmetry of glaciation in the British Columbia Coast Mountains

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The aspect most favoured by glaciers in the Southern Coast Mountains is north-northeast, due to both solar radiation incidence and wind effects. Although asymmetry of glacier numbers is strongest in the sunnier, landward ranges around Bridge River and Cayoosh Creek, with vector strengths as high as 90%, it is found also in wet, cloudy coastal ranges, with vector strengths of 20-60%. Asymmetry can be measured also by Fourier Analysis of the azimuthal variation in glacier altitude, giving north: south differences exceeding 200 m in the drier ranges. Glaciers in some adjacent areas show the following north: south differences in altitude (metres), allowing for regional trends: Vancouver Island 40, Olympic Mountains 94, Stikine 109, SW Yukon 177, Washington Cascades 190. These variations again show the effects of regional climate.

Analysed in the same way, cirque floor altitudes provide valuable palaeoenvironmental evidence. In the Coast Mountains, differences are mainly north: south, amounting to 190 m in the Bendor Range and 214 m in the Cayoosh Range. Cirques were formed during phases of intermediate glaciation, with firn lines some 400 m lower than present: these phases were sunny, and the wind regime was not noticeably different to present.

Sediment and carbon budgets for eroding blanket peat catchments: Implications for global change

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Globally peatlands account for circa 50% of terrestrial carbon storage containing as much carbon as is present in the atmosphere. The uplands of the U.K. have an extensive cover of blanket peat but much of it is actively eroding. This paper presents a detailed sediment budget for a blanket peat catchment in the North Pennines and comparative data from a catchment in the Southern Pennines. The catchments have sediment yields of 44 and 509 t km^2 a^{-1} respectively and represent two extremes of a spectrum of eroded peat catchments. It is demonstrated that the lower sediment yields in the North Pennines are associated with extensive natural re-vegetation of the catchment and consequent reductions in slope-channel linkage. Construction of a carbon budget for the North Pennine catchment demonstrates that particulate carbon losses associated with the fluvial suspended sediment load are the largest single carbon loss from the system. The system is currently close to carbon neutral but much higher carbon losses associated with actively eroding systems such as the South Pennine site would make these systems a major carbon source. The possibility that enhanced summer temperatures and winter storminess will accelerate erosion of upland mires means there is a risk that physical degradation of peatlands could become a significant positive feedback on global warming.

Dissolved transport in the na Borges basin, Mallorca, Spain

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The aim of this study is to provide the major findings to emerge from a research on the transport of dissolved elements in the river network (327 km^2) of the na Borges basin, Mallorca, Spain. The basin is underlain by limestones, marls, and dolomites. Dry crops, 80.2 % of the basin, dominate land use. Data collection programme has been undertaken using an automatic water sampler (ISCO) installed in the mainstream and manual suspended-sediment samples collected along the river network. Results show important differences in dissolve behaviour between base flow and flow events. The tributary sa Franquesa, at the headwaters, is the main dissolved contributor with a maximum conductivity of 1233 µS/cm during a flow event, and 2050 µS/cm during base flow. Maximum conductivity during a flow event in the main stream (1250 µS/cm) was registered during the peak discharge in a 96 hours flood. No one of the highest concentration elements raise dangerous water quality concentration, although there are important concentration of pollutants as NO_2^- with maximum of 0.055 ppm in the sa Cabana tributary and 0.059 ppm in the main stream. The dry crops land uses and three water treatment plants are the main ions sources contributors.

Sedimentary environment change of Wanquan River Estuary, Hainan Island, China

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^{210}Pb geochronology and sediment core profiles of organic carbon, total sulphur and organic carbon isotope ($\delta^{13}C$) values were used to reconstruct the local environmental history of the Shamei Lagoon, located in the Wanquan River Estuary, eastern Hainan Island, China. Total sulphur and $\delta^{13}C$ values decreased upwards in the top 30 cm of a sediment core that spanned the last 200 years of deposition. Total sulphur concentration and $\delta^{13}C$ values respectively decreased upward from 1.92% to 0.36%, and -20.63‰ to -23.64‰.The C/S ratio in the 19th century and earlier was relatively stable in the range of 0.47-0.80, and there was a positive correlation between organic carbon and total sulphur. Since around 1900, the C/S ratio increased rapidly to a maximum of 3.94, but no simple correlation was found between organic carbon and total sulphur during this more recent period. These results indicated that before AD 1800, the lagoon had a fully marine character, and the location of today's Wanquan River Estuary was an open embayment. From 1800 to 1900, the salinity of Shamei Lagoon decreased noticeably. The amount of seawater which could enter the lagoon decreased gradually as the Yudai spit grew. Today, seawater scarcely affects the lagoon; it is essentially a freshwater basin.

Sedimentation in large lakes in the Cordillera: Implications for Late-Pleistocene deglaciation and changing Holocene sediment sources

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Large lakes in the major valleys of the Cordillera of British Columbia integrate in their sedimentary records the sources of sediment in their drainage basins, the processes that delivered the sediments to the lake and deposited them there, and the environmental changes since deglaciation of the lake basin. The eleven lakes described in this study have been assessed by sub-bottom acoustic survey and analysis of core records. Their sedimentary environments include those with high rates of accumulation early in the Holocene but low input presently, those with sustained high rates of accumulation throughout the Holocene, and those with consistently low rates of accumulation despite their situation in regions of high relief and continued glaciation. From these conditions geomorphic and glacial history may be inferred and changing sediment budgets assessed. In addition, the changes in sedimentary processes in the lakes as a response to environmental processes is documented.

Littoral sediment dynamics of the Embayed Bay of Plenty Coast, New Zealand

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The broad embayment of the Bay of Plenty encloses the largest sandy littoral system of the indented east coast of New Zealand. On the eastern side, the littoral system comprises greywacke gravels from the Motu River system which grade into pebbles, and then sand moving westwards until about Ohiwa Harbour. On the northern side, Waihi Beach is the limit of the sandy littoral drift system, based upon sediment mineralogical evidence. The sediments along most of the littoral system derive from the acid Taupo Volcanic Zone (TVC). From numerous geomorphic indicators, net wave driven littoral drift from Waihi beach is toward the southeast. However this drift is semi-interrupted by the major tidal inlets of Tauranga Harbour, and more notably from the gently protruding headlands of Town Point and Kohi Point. The meeting place of the opposing littoral drift systems is about Ohiwa Harbour, which has been undergoing rapid infill sedimentation since the sea attained its approximate present level about 6500 years ago. Paradoxically, offshore from the Tauranga-Waihi Beach sector in the northwestern sector of the embayment, inner shelf and shoreface net sediment movement is towards the north, driven by offshore directed wind stress effects and shelf currents. It is not known whether this offshore sediment transport pathway extends to the eastern Bay of Plenty.

The Watershed Processes and Forest Management Simulation: Modelling sediment movement on hillslopes and in streams

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The long-term objective of this research is to identify potential trade-offs between forest management strategies and acceptable bounds of aquatic habitat conditions. The Watershed Processes and Forest Management Simulation provides an integration of plausible representations of several key influences of forestry practices on fish habitat in small and intermediate streams in coastal BC. The model simulates storm peakflows. Debris slides and bedload transport in channels are modelled. The recruitment of wood into channels and the dynamics of log jams are simulated. Changes in channel morphology are tracked and coho salmon habitat capability is rated. Forest harvesting is simulated to produce diverse cutting patterns.

The model produces expected trends. In the absence of riparian buffers log jam numbers decrease with increasing harvest volume. Bedload yield increases with increasing debris slide rates and decreasing log jam numbers. Coho salmon habitat capability rating decreases with decreasing log jam numbers.

In my talk I will focus on how the model simulates sediment movement on hillslopes and in streams. I will discuss the structure of the debris slide module (incl. the initiation and deposition probability functions). I will also outline the simulation of bedload movement through the Bagnold equation, and its interaction with log jams.

The use of sediment budget concepts to assess the impact on watersheds of forestry operations in the southern interior of British Columbia

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Sediment budget concepts can be applied to the assessment of the impacts of forest resource development on the sediment regime of streams. In British Columbia, these impacts are of concern because of the extent of commercially valuable forests. Increases in sediment yield from forestry operations can affect water quality, fish habitat, and channel stability. To address these concerns, the BC Ministry of Forests conducted several sediment budget studies from about 1992 to 2002. This paper reports the results of two studies, focusing on the water quality of streams used for community water supply. The studies address several questions: How sensitive are the streams to an increase in sediment supply? Are development-related sediment sources significant compared to natural sources? What forest practices are responsible for increasing or minimizing sediment impacts? How can the impact of forestry operations on water quality be monitored? The studies concluded that erosion from forest roads can be a significant source of suspended sediment, but sediment from logging operations is usually negligible. The risk of landslides is an important factor in the sediment budgets, but is difficult to quantify. Differences in geology and groundwater regime can influence the sensitivity of watersheds to sediment impacts.

Earth-surface environmental processes in the eastern margin of the Tibetan Plateau inferred from lake-catchment systems

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Several lake-catchment systems in southern China (Yunnan) have been studied for revealing hydro-geomorphological environment in the eastern margin of the Tibetan Plateau by using sediment information in lakes and their surrounding environmental information. This district is located in climatically and tectonically sensitive zone; its climate is controlled by Asian monsoon and it has experienced occasional earthquakes. Lake sediment records in this area include information on hydro-geomorphlogical changes as well as earthquake activities. Analytical results for sediments show gradual aridification with some humid conditions since 3000 yr B.P., indicating similar trend to East Asia including Japan. Sedimentation rate in the last some decades for each system here is related to its catchment environment; mainly land cover conditions and rainfall characters.

Rainfall magnitude and spatial patterns of sediment sources in an arid and humid watershed in Israel and Germany

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Spatial heterogeneity within small watersheds can lead to non-linear response of surface runoff with increasing magnitude of rainfall events. One reason for the non-linearity is the degree of connectivity of runoff generating areas within small watersheds. The extent of the runoff contributing area can increase significantly once a threshold of rainfall intensity or amount has been crossed, enabling the movement of sediment from previously disconnected source areas to the valley channel.

In this study, the effect of rainfall magnitude on patterns of runoff generation and connectivity within two small watersheds, one in the arid Zin Valley Badlands of the northern Negev, and one in the humid Eifel region west of Trier, Germany, is examined, and their implications for sediment transport in watersheds and implications for assessing the impact of past and future climate change are analysed.

In the Zin Valley Badlands, a strong increase of infiltration between ridges and valley sideslopes leads to frequent discontinuity of runoff. Sediment eroded on the ridges is deposited on sideslopes. Only in areas where topography favours concentration of runoff, such as concave valley heads, continuous flow is frequent, leading to transport of sediment from slopes to valley channels. This distribution of source areas is controlled by the duration of high intensity showers, sufficient to be runoff effective in valley heads, but not on sideslopes. The significance of the differentiation of sediment source and storage areas in the small badland watersheds is reflected by soil properties and topography, highlighting the significance of rainfall characteristics for long-term landscape development.

In the Eifel, runoff is commonly generated along valley floors where high groundwater tables lead to surface overland flow. However, on the plateau-like flat hilltops, rainfall, often combined with snowmelt, can overcome infiltration capacity and produce surface runoff to the valley channels. The frequency of such events is relatively low (0.5 pa) and therefore ridge areas are not considered to be a sediment source area in land use planning. However, on the ridges manure is often applied days or weeks before a high magnitude storm and prone to erosion during such an event. While currently not considered a problem, more high intensity storms in the future may require a change of land use policy to limit non-point source pollution.

The importance of the major typhoons and earthquakes on mass-movements and sediment supply, a case study of the Hoshe Basin, Central Taiwan

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Unit sediment yield of the Choushui River in the central Taiwan is extremely high. Sediments mainly originate from mass-movements in the numerous low-order basins. It is believed sediments are transported efficiently due to the steepness of the channels mainly during typhoon seasons. This paper focuses on one of these headwater basins, the Hoshe Basin, a tributary catchment of the Chenyulan River, which joins the middle Choushui River from the south. Particular attention is paid on the impact of three major events on triggering mass movements, two extreme typhoons (Herb in 1996 and Toraji in 2001) and the disastrous Chichi earthquake (with magnitude 7.3) in 1999. They all caused extensive landslides and/or debris flows in the Hoshe River. Spatial distribution and the area of the landslides before and after three events were identified from the rectified aerial photographs of the basin. Topographical, geological, and geomorphic characteristics of slopes and channels were examined. The role of the occurrence of a major earthquake before a high-magnitude typhoon and the land use history in the basin were also discussed.

Integrating a sediment budget framework with a numerical model of drainage basin evolution for coastal British Columbia

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The sediment budget concept has been applied successfully to a variety of field settings to better understand sediment sources and sinks in drainage basins. The sediment budget framework also has significant potential to provide a powerful tool for better understanding sediment cascades in numerical models of drainage basin evolution. In this study, a sediment budget framework is integrated with a numerical model of drainage basin evolution for coastal British Columbia. The surface model, LandMod, simulates sediment transport processes for hillslope and channel systems, and also tracks sediment supply by the inclusion of a weathering term. Using a sediment budget framework, the inputs and outputs for sediment reservoirs identified in the model landscape are evaluated. The nature of links between transport and storage for these reservoirs are explored. Weathering processes are critical to understanding sediment routing as they are responsible for supplying sediment to the system. The integration of a sediment budget framework within LandMod allows the sensitivity of sediment transfers to weathering rates to be more fully examined.

Sediment production, transport, and yield in proglacial environments: Integration of numerical models and the stratigraphic record

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Sediment yield in mountain environments is a complex and poorly understood index since clastic material can originate from numerous geomorphic processes and can be intermittently stored in hillslope, fluvial, and glacial environments. The construction of a sediment budget can facilitate the partitioning of sediment yield records but may be significantly biased if the budget is based on contemporary rates of sediment transfer. To reduce temporal bias, two methods are commonly employed; a) numerical-models of sediment production and transfers and; b) reconstructing long-term patterns of sediment delivery or storage from sedimentary deposits. Surprisingly, there have been few attempts to integrate both approaches to improve our understanding of sediment transport in mountain environments. To address this deficit we develop a simple box model of sediment production and transport for a proglacial, Coast Mountain watershed and compare the modeled sediment yield to the sediment record preserved in the watershed's outlet lake basin. The model consists of coupled sediment reservoirs (boxes) representing subglacial, glacier forefield, fluvial, and hillslope components. Sediment production occurs sub-glacially and through detachment from upland, snow free surfaces during rainstorms. Glacier fluctuations are driven using long-term temperature reconstructions for the Northern Hemisphere. Fluvial sediment transport occurs during periods of ice and snow melt and during rainstorm and snowmelt-generated floods. Model output is compared to a 3000-year sediment yield record reconstructed from varved sediments preserved in the outlet lake basin.

The influence of organic matter sources on sediment transfers and storage in riverine environments: An overlooked component in the sediment flux process

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The transport and storage of inorganic silts and clays through aquatic systems are a vector and a sink for adsorbed nutrients and contaminants, which are known to be detrimental to the aquatic habitat and the water quality. While geomorphologists have recognized these advective factors in their calculations of geochemical budgets, another important component influencing the process of inorganic sediment transfer and storage is still most often overlooked. The presence of dissolved and particulate organic matter is associated with the formation of composite aquatic particles, which due to their increased size have altered transport and entrainment characteristics compared to their constituent materials. The short term storage of sediments on the channel bed and the potentially longer storage within the gravel matrix have been shown to be mediated by the presence of organic matter contributed to the stream. Examples from stable isotope analysis of suspended and gravel stored sediments will be presented to indicate the role of both terrestrial and stream derived organic material in modifying the size, shape and settling characteristics of the aggregated fine grained sediment. The quality of the organic matter as opposed to the quantity delivered to the stream appears to be the more important factor in regulating aggregate formation.

Alluvial fan morphology in the Harper-Avoca, South Island, New Zealand: Coupling, sediment supply and timescales

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This paper presents ongoing research into the roles of coupling and sediment supply in the evolution of alluvial fan morphology in the Harper-Avoca catchment, New Zealand. The study basin is ideal for this work since it contains a series of fans with contrasting morphologies while significant human activity is limited to the last 150 years. Landform evolution data have been derived for the last half-century by analysis of archive aerial photographs. Patterns of landform evolution over longer timescales are being reconstructed on the basis of the pedogenic characteristics of soils developed on terrace surfaces. These data reveal significant variation in temporal patterns of fan evolution over a distance of c. 10 km. This variation is analysed in the light of evidence for temporal and spatial variation in environmental controls derived from archive land-use, climate and sediment source records and published palaeoenvironmental reconstructions. This ongoing analysis demonstrates the need to develop appropriate quantitative models to formalise and test understanding of landform evolution.

Sediment budgeting in the Mississippi River delta – the key to coastal restoration

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Efforts to combat dramatic coastal land loss in Louisiana face a fundamental sediment budgeting challenge. Can the subsidence of the landscape be counteracted by effective distribution of Mississippi River sediments? This presentation will present two approaches to this question based on vertical land building and horizontal landscape expression that encompass different temporal scales of sediment delivery and land building. Vertical assessments of sediment need are frequently based on data derived on multi-year to decadal times scales and can be heavily influenced by episodic events such as floods or hurricanes, while landscape analogues provide a more integrated view of sediment delivery and capture in coastal deltas over time scales of decades to centuries. Sediment budgeting at the coast over these longer time scales is also confounded by changes in sediment delivery within the basin. Effective assessments of both sediment need and sediment availability are vital to both efficient use of sediment resources and clarifying expectations of what restoration efforts can accomplish.

Simulation of long term degradation below dams by a coupled alluvial flow model

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The performance of a coupled numerical model of alluvial flow in simulation of long term degradation below dams is compared with that of an uncoupled model. The uncoupled model is the well-known IALLUVIAL sedimentation program and the coupled model is a newly developed non-dimensional model of riverine flow called COUPFLEX. The models are applied to the same examples used to substantiate the reliability of the uncoupled model by the respective developers. Application of the models to the examples, associated with long term degradation of river bed downstream from a dam, reveals the preferability of a coupled approach. The strong inter-relation between water and sediment components of alluvial flows is recognised in the coupled approach and this gives it advantages over the traditional uncoupled method in which the calculations of the water flow and bed level variations are separated to various degrees. Simulation of these tests highlights three beneficial aspects of a coupled approach. The simulations show that a coupled model (i) gives more accurate results when rapid river processes are involved, (ii) obviates some computational difficulties such as production of false bed level oscillations, and (iii) allows more flexibility in the selection of the size of the computational time step. It was therefore concluded that while computer programs such as IALLUVIAL are useful tools in dealing with most laboratory and field applications, for the development of new commercial computer programs of alluvial flows consideration of the coupled method as opposed to the traditional uncoupled methods seems inevitable.

Sediment and nutrient balances and scaling effects in a Himalayan watershed

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Over the past 14 years nutrient and sediment dynamics have been monitored in a Middle Mountain Watershed of Nepal. Using nutrient budget techniques it was shown that there has been a dramatic shift in nutrient deficits and surpluses. Nitrogen and phosphorus deficits have been eliminated in intensively used irrigated fields due to the availability of fertilizers though foreign aid. However, potassium and calcium deficits are now emerging as a widespread problem. Using erosion plot studies and sediment monitoring stations in different locations in the watershed it was found that the greatest nutrient losses occur in the rainfed agricultural areas located in the upper portions of the watershed but part of these losses become nutrient enrichments in the lowland irrigated field. Scaling effects of the sedimentation processes show the average annual erosion rates at the plot scale vary between 20-30t/ha/y but these drop to less than 10t/ha/y at the watershed scale. In contrast, the phosphorus losses in sediments between the plot and the watershed scale are significantly lower. This is attributed to two factors: a) sediments originating from degraded sites which make up a higher proportion of the sediment load, usually contain lower phosphorus levels, and b) a considerable proportion of the suspended sediment gets deposited in lowland irrigation fields. The results show that to control nutrient losses conservation efforts should focus on upland agricultural fields. In contrast, to reduce sediment loads that adversely affect irrigation channels in the lowland, requires that degraded areas need to be rehabilitated. To sustain a long-term production system both activities need to be carried out at the same time.

Integration of energetics in sediment budget studies – a useless exercise?

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Most sediment budget studies are characterised by the calculation of sediment production rates with values shown in t/km²/yr. There are only a few examples where energetics have been applied as an integrative framework for sediment budgets, whereas energetic approaches are well established in disciplines such as meteorology and geophysics.

The objective of this presentation is to discuss the integration of energetic approaches into sediment budget studies. Classic papers are therefore revisited and compared with new data from the European Alps.

Valuable pioneer studies on the quantification of vertical and horizontal mass transport of different processes were carried out for the Alpine Rhine (4300 km², European Alps) and Kärgevagge (15 km², Northern Sweden) by Heinrich Jäckli and Anders Rapp, respectively. Many data of these and other studies, however, are rough estimates and proceed from differing measurement periods. Therefore it seems reasonable to make a re-evaluation of the concept of geomorphic work in line with Nel Caine and based on data derived from accurate measurements.

Nonwithstanding the value of the established concept of mass units and their derivatives, it is presumed that mass distance units and/or energetic units may help to better understand the process-form paradigm in relation to sediment budget studies.

Lake sediment records of watershed change: Phosphorus geochemical proxies from alpine environments

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Most lake sediment based studies of mountain geomorphology have focused on quantifying rates of erosion from contributing watersheds. Studies of mineralogy, bulk metal geochemistry and elemental ratios, amongst other proxies, have provided additional insight into the nature of the inflowing sediment, and by inference the weathering of soils on surrounding slopes. In this presentation, we will present results of exploratory work that examines the phosphorus geochemistry of alpine lake sediments. The basic premise is that the geochemistry and accumulation rates of the phosphorus in the lake sediments over time reflect the effects of changing conditions in the adjacent watersheds (climate, soil and ecosystem development) and landscape stability. As a biolimiting nutrient, phosphorus variability also gives insight to ecosystem status and development, and plays a clear role in reconstructions of the biological cycle and the global carbon budget. The general approach will be described along with results from headwater alpine lakes in the Coast Mountains of British Columbia, Sierra Nevada, and a mid elevation site in Costa Rica. Interpretations in terms of watershed-scale slope development, sediment sources and erosional processes, human disturbance and aridification will be presented.

A simple sediment budget model to estimate long-term contaminant export from small catchments

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A simple geographical information system based sediment index model was applied to estimate contaminant losses from catchments due to soil erosion. This model provided a relative measure of erosion and deposition, which could be related to observed contaminant inventories in the soil profile using least squares regression. The intercept of the regression equation represents the mean contaminant inventory under absence of erosion and deposition. The difference between the mean observed contaminant inventory and this intercept could be interpreted as the time-integrated contaminant loss from the study area. This presentation will illustrate this approach for the estimation of export of copper fungicides from two vineyards in south-eastern France and the export of Chernobyl-derived radiocaesium from a small catchment in western Slovakia. The advantages and disadvantages of this approach compared to the use of reference sites will be discussed.

Reservoir sedimentation and downstream riverbed degradation in the lower Ebro River (NE Spain)

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Large dams profoundly alter the fluvial regime and the sediment transport of the lower reaches of the Ebro River, the largest in the Iberian Peninsula and one of the most regulated watercourses in Europe (e.g. rate of impoundment = 60% of annual runoff). In particular, dams change the downstream flood timing, advancing the peaks for flood control purposes, and the sediment transfer, since reservoirs retain almost all-incoming sediment. Within this context, we monitor, especially during floods, the sediment transfer through that highly regulated fluvial system, by means of sampling suspended and bedload upstream and downstream of reservoirs. A total of 2 x 10^6 tones of sediment (98.5% in suspension and 1.5% as bedload) entered the reservoir chain during the wet hydrological year 2002-03, most of them transported during the T_5 and T_{10}-year floods of February and March. Downstream the dams a total of 0.4 x 10^6 tones of sediment (50% in suspension and 50% as bedload) were transported during the same period. Sediment was necessarily entrained from the riverbed and channel banks and not replaced with upstream-coming particles. This phenomenon has led to an annual incision of 40 mm (56 mm according to the survey of scour-chains) over the 27 km-long study reach below the dams. Deficit of sediment worsens due to systematic dredging of the channel, at a rate of 50,000 t/y, to make the river navigable to enhance the tourism in the region. Altogether constitutes a significant step towards the long-term degradation of the lower Ebro River and its delta plain.

River-Sea Interaction and the Eastern China Plain Evolution

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River-sea interaction has impacted greatly on the formation of the eastern plains of North China. In particular, the Yellow River and its tributaries have transferred vast volumes of sediments from the Loess Plateau to the sea. From the Pleistocene to the present, great volumes of sedimentary materials have been deposited on the North China Plain. The North Jiangsu Plain located on the northern side of the Changjiang River (35°to 31°30'N, 118° to 122°E) is another example formed by river-sea interaction. The plain is 200 km wide as measured from a series of lakes in the west located at the foot of small hills and low mountains arranged in arc-shaped bay patterns towards the Yellow Sea. The Grand Canal was dredged through these lakes and depressions in the 7 century some 1400 years ago. On the east side of the plain, an artificial dike was constructed along a band of coastal chenier ridges during the Song Dynasty (1127 AD). But at present that dike system is 40 km inland to the west of the present shoreline. There is a sandy ridge field off the North Jiangsu Plain in the southern Yellow Sea. Geomorphological research indicates that this sand field was deposited around 30,000 a B.P., at which time the Changjiang River had migrated north to enter the Yellow Sea in the Qianggong area of the present North Jiangsu Plain. The river deposits were reworked by strong tidal currents driven by > 9 m tidal ranges during the post-glacial transgression and a period of higher sea level. At present the sandy ridge field occupies an area some 200 km long from north to south, and 150 km wide from land to sea in a radiative pattern. The total area is c.20000 km^2 consisting of 70 ridges with deep channels between them. Water depth of the offshore sandy ridges is c.10-20 m, but with 1/10 of their area above sea level. With the protection offered by the offshore sandy ridge field, tidal flats developed along the coastline behind these ridges, even though the Changjiang River had shifted back to the East China Sea, and the Yellow River returned to the Bohai Sea. This formation mechanism may indicate the way that the North Jiangsu Plain formed in the past.

This present study was carried out on the inner plain to trace more evidence of an original west boundary of the Yellow Sea, and has been stimulated by the discovery of several salt mines which were discovered buried in the inner part of the plain.