Science and the Desiccationist Discourse of the 20th Century

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SUMMARY

Recent ecological research has questioned the scientific validity of a number of environmental disaster scenarios, particularly those centred on the causal linkages between deforestation and desertification and intensified flooding. This essay explores the progression of theoretical models and empirical research linked to the understanding of the capacity of forested systems to regulate the hydrological regimes of a given area. Drawing upon writings of American and Indian foresters, I suggest that a diversity of viewpoints with regard to the climatic and protective capabilities of forests, expressed during the late 19th and early 20th centuries gradually gave way to a more unified – and highly alarmist – 'desiccationist' discourse by the middle of the 20th century. This position has been sustained within much of the popular press as well as in the publications of numerous conservation agencies, despite being based on models of forest functioning discredited in the ecological literature since the 1920s. This essay documents this transformation, and explores some of the factors that may have helped in the production of this powerful and lasting discourse on degradation.

I. INTRODUCTION

> ... that the desert's edge is gradually shifting southward there is little doubt. The spread of the Sahara has probably been measured most precisely in the Sudan. There, as elsewhere, vegetational zones are shifting southward as a result of overgrazing, woodcutting and accelerated soil erosion.[1]

> ... no woody species has been eradicated from the area, no ecological zones have been shifted southwards and the boundaries between different vegetation associations appear to be the same now as they were 80 years ago.[2]

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The contradictory nature of the above statements is illustrative of some of the confusion that exists regarding the scientific validity of much of the discourse on environmental degradation, particularly in the context of land-use practices within the Third World. Recent research points to an absence of empirical data to support particular scenarios of degradation; an absence of long-term data to enable the detection of directional trends, such as the southward advance of the Saharan desert; a failure to separate naturally occurring processes from those induced by human activities; and a failure to distinguish seasonal from permanent changes in vegetation cover.[3] There is growing recognition within the academic ecological community of the complexities of ecosystem functioning, and the limits to our predictive and explanatory capabilities with regard to large-scale ecological phenomenon.[4]

And yet there remains within the popular press, the writings of some environmentalists, and conservation agencies in various parts of the world, a deep-rooted conviction of the disastrous, civilisation-threatening consequences of deforestation.[5] A good example of such thinking can be seen in the writing of the well known environmentalist Norman Myers. Describing the consequences of deforestation in the Himalaya, Myers states that

> Primarily because of deforestation in their headwater regions, the river systems are increasingly subject to disruption, leading to floods followed by droughts.... All in all, these plains have been described as the 'greatest single ecological hazard on Earth.'... The Himalayan forests normally exert a *sponge effect*, soaking up abundant rainfall and storing it before releasing it in regular amounts over an extended period. When the forest is cleared, rivers turn muddy, and swollen during the wet season, before shrinking during drier periods.... Flood disasters are becoming more frequent and more severe.[6]

There are numerous problems with such writing, the most significant of which is the absence of data, and the overwhelming reliance on a model of forest functioning that has been discredited since the 1920s (as discussed below). A recent review of the evidence of Himalayan degradation suggests on the one hand the lack of adequate long-term empirical data to confirm any trend in change in flooding intensities in the Indo-Gangetic plains over the past few decades, while also pointing out that high rates of flooding as well as high rates of erosion in the Himalaya are better explained by some combination of factors, including tectonic instability, the naturally erosive composition of many parts of the Himalaya, and cyclical episodes of high intensity rainfall, rather than the common tendency to explain ecological phenomenon as resulting solely from the land-use practices of growing human and livestock populations.[7]

The theoretical foundation of the conviction that deforestation is explicitly linked to changing hydrological regimes is centred primarily on the notion that forests act as sponges with regard to the conservation of a region's water supplies. The bare bones of this forest-acting-as-sponge model is that forests

serve to interrupt rainfall, giving rain-water time to slowly percolate into the soil, with a part of it being absorbed by the humus that is part of the forest floor. This water is then released slowly by the humus over the course of the year, providing year-round, regular flow to streams. In the absence of forest cover and a thick humus layer, water is expected to rush off mountain slopes at the time of the rain, leading to flash floods during the monsoon, and dry streams during the rest of the year. Thus alternating cycles of drought and flooding are seen as the principal consequences of deforestation.

This sponge effect has been discredited within the ecological literature for much of this century. Drawing on research over the past 60 years, Bosch and Hewlett point out that the removal of tree cover leads to a *year round increase* in water flow, owing to the reduction in transpirational losses associated with dense forest cover.[8] Deforestation need not, therefore, lead to alternating cycles of flooding and drought.

Based on archival and field research in the state of Himachal Pradesh (formerly part of the Punjab) in the north-Indian Himalaya, I have argued elsewhere that an exaggerated discourse on degradation explicitly linked to high grazing pressures, can be traced, ultimately, to a sustained power struggle between the Punjab Forest and Revenue Departments.[9] The alarmist international discourse of the 1930s undoubtedly fuelled degradation concerns within the Punjab Forest Department, but I have argued that the resistance of the more powerful Revenue Department to Forest Department efforts to gain greater departmental control over forest lands, led ultimately to the latter's adoption of a specific model of forest functioning, one that provided a predictable and alarming account of the consequences of subsistence land-use practices.[10] I have argued, therefore, that forest policy was critically influenced by the institutional context within which policy was being formulated, countering earlier analyses of forest policy as being either driven by colonial economic concerns or ideological concerns regarding environmental degradation.[11]

This essay examines the chronological progression of the desiccation debate,[12] and I have located my analysis in the broader scientific context within which these ideas were articulated during the late 19th and early to mid-20th century. I explore the connection between a scientific paradigm[13] of a given era, and bureaucratic use of this science to justify a particular position. My basic argument is that while available scientific ideas have provided material for the formulation of this discourse on Himalayan degradation, the institutional context within which the discourse has taken place, has, in a sense, shaped or directed the discourse. Over time, one observes a two way process, whereby bureaucracies may use science to inform a particular rhetoric; at the same time, bureaucratic rhetoric comes to influence the scientific discourse itself, and, thereby, the very nature of science. Such an influence is likely to be particularly noticeable where members of the concerned bureaucracy are trained scientists, and hence capable of making 'informed' statements on scientific issues. Over time, a

particular discourse may be shaped by the bureaucratic terrain it traverses, but because of the expertise associated with the bureaucracy, the discourse may come to acquire a legitimate scientific standing independent of the bureaucratic context within which it matures.

Two recent studies have examined the historical origins of contemporary environmental concerns.[14] Grove's analysis locates these origins in 17th century colonial experiences of deforestation within fragile island environments. The argument is an important deviation form explanations that see environmental concerns as originating in 19th century Europe and the United States. His study extends to the year 1860, just prior to the formation of the Indian Forest Department, and Grove rightly points out that conservationists such as Cleghorn and Gibson played on governmental fears of the environmental consequences of deforestation, in canvassing for the establishment of the Indian Forest Department. Countering Grove's assertion that concerns about the environment were originally a colonial experience, Rajan stresses the fact that the desiccating influence of deforestation was a well-discussed phenomenon in 17th century Europe, and was, in fact, a primary factor used by European foresters to press for the establishment of forest reserves in France and Germany, and for the institutionalisation of forest conservation.

Rajan proceeds to suggest that these ideas, with their essentially European roots, retained a primary influence on the direction taken by conservation policy in the British Empire, and in science more generally up until the 1960s. While he provides a fascinating description of the scientists and environmental ideas of the 18th and 19th century, his analysis suggests a general stasis with regard to the evolution of models of forest functioning. Indeed one gets a sense that ideas linking forests to climate on the one hand and the conservation of water on the other, did not materially change from the 17th century onwards, and that the theoretical ideas underlying our current understanding of environmental degradation were essentially developed by the 17th century. In the process he fails to note that the models he is describing, as late as the 1960s, had begun to be discredited by the 1920s, and that ecological research since has overturned some of the most cherished notions regarding the protective and climatic capacities of forests. That the older models continue to be used in various fora and discourses, despite the absence of empirical or theoretical support, suggests the need for locating the history of these ideas within contexts other than merely the writings of prominent European conservationists.

I will make three primary arguments in this essay. First, contrary to Rajan's analysis suggesting an overwhelmingly European influence on Indian forester thinking during the 19th and 20th centuries, I will argue here that by the 1920s Indian foresters were drawing more heavily on the writings of their American rather than European counterparts. While this may be seen as merely a detail with regard to the historiography of Indian (and, as I shall point out, African) forest policy formulation, such a scenario would indicate the need for a more detailed

analysis of the context within which these ideas were being shaped in the United States during the 1920s and 1930s, a context that has been largely ignored by both Indian and African historians of forest policy.[15]

Second, I will argue that the desiccationist discourse of today has emerged from a diversified set of views in the 1920s, into the uniform and alarmist rhetoric that characterises forester and environmentalist positions today. Empirically driven findings of the early 20th century posed a critical challenge to mainstream forester conceptions of the protective capabilities of forests. While these findings have since been replicated repeatedly within the scientific literature, dissension and debate has gradually faded from popular writings as well as writings by Indian foresters.[16] This transition within Indian forestry circles, I argue, is due to selective use of data and ideas by foresters and a simplification of inherently complex ecological phenomena. This selectivity and simplification can be linked to the continuing need on part of the Forest Department to provide a clear-cut reasoning for more stringent forest conservancy, particularly in the face of continuing opposition from the Revenue Department. Elsewhere I have provided a detailed analysis of the conflict as it took place between the Punjab Forest and Revenue Departments.[17] Accordingly, I will not detail the dimensions or contours of this conflict in this essay.

And third, I will argue that ideas within Indian and American forestry have diverged since the 1930s, becoming far more quantitative in the latter, and remaining largely rhetorical, and non-experimental in the former. This difference is due, at least in part, to differences in the nature of opposition to forester viewpoints in the Indian and American context. Within the United States, forester exaggeration of the environmental consequences of deforestation was in response to inter-agency wrangling over appropriate methods of flood control. Engineers involved in flood-control programs consistently critiqued the non-quantitative basis of American Forest Service predictions. In contrast, the opposition in the Indian context came primarily from nontechnical officials of the Revenue Department, officials lacking the scientific training or credibility to demand more quantitative approaches. I am unclear as to why Indian engineers, geologists and meteorologists were seemingly more accepting of the Forest Department's position than their American counterparts.

I should point out at the outset that I am not suggesting a causal link between developments in the U.S. and those in India. I am not arguing that the writings of Lowdermilk or other American foresters, were a defining influence on the thinking and writings of Indian foresters. My impression is that American foresters were similarly drawing upon the writings of Indian foresters, although an analysis along these lines was not a part of my project. I am arguing, instead, that Indian foresters were drawing upon the writings of American foresters, and a wider international scientific context, doing so ultimately in a highly selective fashion to bolster their case for the introduction of more stringent forest conservation measures. In other words, this larger context of ideas was a

resource that Indian foresters drew upon to advance a particular agenda. And ultimately, it is this selective shaping of a discourse, whether intentional or unintentional, that I am primarily interested in.

The next section of this paper examines the chronological progression of the ideas regarding the climatic and protective benefits of forests as they developed within the U.S. Forest Service between the late 19th century and the 1970s. Section three documents the chronological changes in thinking on forest influences within the Indian forestry community. A concluding section highlights the key insights from the analysis.

II. THE AMERICAN CONNECTION

My analysis of the progression of ideas within the American literature dealing with the climatic and protective capabilities of forests is based on secondary sources, in particular a brilliant, though largely ignored analysis by Ashley Schiff and a shorter analysis by Gordon Dodds,[18] as well as my own reading of primary sources that these and other authors refer to. Based largely on Schiff's analysis, I have tried to provide a chronological progression of the debate within American forestry, highlighting key developments in the thinking and writing of the time. I have outlined this material in some detail, despite the existence of Schiff's and Dodds's analysis, primarily to provide a sense of the material that Indian foresters were drawing upon. My intent has not been to add to existing analyses of why the debate took the particular direction it did within the U.S.

Thinking within European forestry influenced the work of early American foresters and environmentalists. Among the early American writings on the desiccating influence of deforestation was *Man and Nature* by George Perkins Marsh, who made extensive reference to the work of the Frenchman Surrel.[19] Similarly, in three monumental reports on the relationship between forests and climate and forests and stream-flow, Franklin Hough referred almost exclusively to work being done in Europe.[20] Importantly, many of the earliest individuals to shape the American Forest Service, including Fernow and Pinchot, were trained in Germany or France.

European forestry had long held the notion that forests played a crucial role in influencing climate – both through an increase in precipitation and through a moderation of temperature extremes. Widespread acceptance of this notion within the fledgling American environmental community, led to the passage of the Timber Culture Act of 1873, as a result of which applicants could claim 160 acres of land, as long as they agreed to plant and maintain a certain proportion of it under tree cover. The expectation was that an increase in tree cover would greatly increase rainfall, and thereby increase agricultural productivity. Michael Williams suggests that during this period and later in the 19th century foresters

exaggerated this connection between forests and rainfall, at least partially as a means of gaining greater control over forest lands.[21]

By the early 20th century, the focus of the U.S. Forest Service on the role of forests in regulating stream-flow had gradually come to replace concerns regarding forest-climate relationships. During 1908-1911 foresters used such a connection between forests and stream-flow to press for the passage of the Weeks Act. The Act aimed at providing the President with the authority to purchase watershed forests with the express purpose of federally managing them in the interests of protecting commercial interests influenced by the navigability of inland waterways.[22]

Not surprisingly, there was considerable opposition to the passing of such an act, particularly from ranching and timber interests, because of the potential for large blocks of lands to be locked away under state control, and out of bounds to these commercial interests. This opposition led Gifford Pinchot, head of the Forest Service, to state '[T]he situation seems to me to be essentially of the kind that calls for a little rioting.... The only remedy, as I see it, in our form of government, is an outburst of public opinion such as can not be trifled with.'[23] Schiff suggests that the Ohio floods of 1907 presented Pinchot with the opportunity he had been looking for, and Schiff quotes Pinchot as saying '[T]he great flood which has wrought devastation and ruin in the Upper Ohio Valley is due fundamentally to the cutting away of the forests on the watersheds of the Allegheny and Monongahela Rivers.'[24] In contrast, only two years earlier, Pinchot had stated, in agreement with the views of Fernow and Greeley, that 'much of the writing and talking' with regard to the connection between forests and stream-flow, was based on 'little definite fact or trustworthy observation'.[25] Much earlier, in 1893, Fernow, the first Chief of the Forestry Division, found little scientific proof to support the notion that forests influenced stream-flow, and in 1905, Greeley, then Forest Assistant, was equally sceptical.[26]

The notion that forests act as giant sponges in helping to regulate the flow of water in streams received particular emphasis as a result of the leadership and propagandising of Gifford Pinchot following his appointment as Head of the Forest Service in 1905 (Williams 1989: 416-423). Foresters resorted to a growing use of this connection in attempts to force the passage of the Weeks Act. On numerous occasions, foresters made categorical statements of 'fact', while displaying a conspicuous lack of experimental data to support their claims. The following comment on the Ohio floods by forest supervisor F. A. Fenn was typical of comments by foresters of the time:

> The forests provided by nature as a protective cover for the watersheds of rivers are the best possible regulator of stream flow. Maintain that cover and the rivers will be most efficient in the discharge of those functions so beneficial to mankind; destroy it and they become relatively inefficient or positively injurious and destructive because of erratic flow.[27]

Such writings by foresters were contested by both meteorologists and engineers. H. M. Chittendon, head of the Army Corps of Engineers, suggested that the foresters' position was based almost solely on anecdotal and historical experience, with little, if any experience.[28] Chittendon also pointed to the inconsistency within the mainstream forester position, which was the suggestion that deforestation was leading both to decreasing rainfall and increased flooding.

> As a step in the crescendo of gloomy forebodings upon this subject, that have filled the periodicals during the past twelve months, the following from the September *Scrap Book* is the very latest. 'When our forests are gone the streams will dry up, the rivers will cease to run, the rain will fall no more, and America will be a desert!' Considering how large a percentage of our forests has already disappeared, the extraordinary rains in all parts of the United States during the past year are not exactly in line with this dismal prophecy. If one were to judge from the records of the past few years only, he must conclude that deforestation is increasing rainfall.[29]

Chittendon also provided a counter-argument, suggesting that most flooding occurred due to periods of intense rainfall, rather than the removal of forests from a catchment area. He suggested that while forests did play a useful role in preventing excessive water run-off during times of average rainfall, forests tended to exacerbate conditions at the two extremes of water availability – heavy rainfall or drought. The humus layer of the forest floor would absorb rainfall until it reached saturation point. Subsequently, water would simply flow off the layer, as it would off an impermeable surface, leading, thereby to higher rates of run-off than from an area cleared of forest. At times of drought, on the other hand, transpirational losses from a forested area would greatly exacerbate drought conditions.

W. L. Moore, Chief of the Weather Bureau, was equally dismissive of notions that attributed overly protective and climatic capabilities to forests. Stating that there were numerous good reasons to conserve forests for economic reasons, he argued that well meaning, but baseless assertions regarding the benefits of forests could only harm the cause of forest conservation in the long-term. Moore went on to point to work within the U.S. as well as Europe that demonstrated the invalidity of suggestions that forests played significant roles in either increasing rainfall or controlling floods.[30] Similarly, Brooks, Senior Meteorologist with the Weather Service suggested that there was little evidence to support a connection between forests and rainfall.[31]

Owing to sustained criticism of the Weeks bill by engineers and meteorologists, in its final form the bill required that any purchase of land for conservation measures be certified by the Geological Survey regarding the fact that such purchase would 'promote or protect the navigation of streams on whose watersheds they lie'.[32] The Wagon Wheel Gap experiment, initiated in 1910, was the first systematic attempt by the U. S. Forest Service to experimentally evaluate the impact of the removal of forest cover on stream-flow. Stream-flow from two

adjoining watersheds was monitored over a nine year period, after which forest cover was cleared from one of these watersheds, leaving forest cover on the other watershed intact, to serve as a control. Stream-flow was monitored from both the experimental and the control watersheds for an additional nine years. Interestingly, deforestation of the watershed resulted in an increase in run-off following the removal of forest cover, an increase that was sustained through the year, thereby negating the twin prediction of an increase in flood waters, and a decrease in dry season stream-flow.[33]

The Wagon Wheel Gap investigation was patterned after an ongoing investigation in Europe, conducted near the town of Emmenthal, in Switzerland, with one critical difference. The Emmenthal experiment compared run off from two adjoining watersheds, with differing levels of tree cover. The experiment demonstrated that the watershed with greater tree cover lost a greater amount of water from transpiration and from evaporation of water from the vegetation surface, while a greater amount of water was evaporated from the soil of the watershed with less tree cover. Making a categorical statement on the impact of forest destruction on stream-flow was however not possible, owing to the fact that there was no experimental removal of forest cover as part of the experiment. The Wagon Wheel Gap experiment was intended to fill this lacuna.[34]

The Emmenthal and Wagon Wheel results represented an essential overturning of ideas that had long been held sacred within the forestry community. However, the results from the two studies were unlikely to change opinions overnight. Also, any admission that forests may not, in fact, provide the kind of protection that foresters had argued for thus far, would simply play into the hands of the Corps of Engineers, over the continuing battle over the apportioning of flood control funds. An editorial in *American Forests* in 1937 points to the huge discrepancy in the funding for flood control works by the two agencies: $2,500,000 allocated under the Weeks Act, for the purchase of forest lands located at the headwaters of large rivers; in contrast, $10,000,000 were allocated that year for surveys and planning by engineers, and $310,000,000 for the building of levees, reservoirs, spillways and dams along the Mississippi.[35]

Chittenden's paper resulted in three sets of investigations being undertaken by the Corps of Engineers - on three major river systems - the Merrimac River (Burr), the Tennessee River (Hart) and the rivers of the Wisconsin State (Mead).[36] Burr concluded that the '[v]ariations in stream-flow are determined essentially by variations in climatic conditions which vary more in irregular cycles independent of forest conditions'.[37] Hart was equally categorical in his denial of the role played by forests in regulating stream-flow:

> The hydrographic records of the two streams so far as they have been kept seem to point out plainly the fallacy of the claim that deforestation is noticeably injuring the navigable capacity of our rivers and I have examined these charts with minuteness but can find no trace of any effect on the quantities of precipitation or on the fluctuations

> of stream flow that may be recorded as resulting beyond question from cutting of our forests .... The indications point in an opposite direction.[38]

In a perceptive paper written in 1930, Lowdermilk pointed to the uncertainties in the understanding of the relationship between forests on the one hand and hydrological regimes and soil erosion on the other.

> The literature on the influence of forests and vegetation on stream flow, flood control, and erosion covers a period of more than a century, is found in all languages of the modern nations, and totals several thousand separate publications, many of which are difficult or impossible to consult. The majority of the works of this extensive literature are based on historical comparisons of vivid interest but without controls or an empirical investigation or on compilations of other works. Comparatively few scientific studies have been made, because of the inherent difficulty of isolating variables from the complex of interacting factors in watersheds.[39]

Significantly, Lowdermilk's note captures the essential factor responsible for the continuing uncertainty, despite the huge literature on the subject viz: 'the inherent difficulty of isolating variables from the complex of interacting factors in watersheds'.

By the 1920s and 1930s, forester rhetoric was increasingly couched in terms of the critical role played by forests in maintaining soil porosity, thereby ensuring adequate percolation of water into the soil; they also argued that forests were essential to prevent widespread soil erosion. Foresters now pointed to the excessive damage resulting from soil that was carried by flood waters – suggesting that the volume and force of the flood could be increased by a factor of 2-3 owing to the addition of large quantities of soil.[40]

As with the issue of whether or not forests acted as a sponge, there were no data to support the position that deforestation was responsible for the large silt load within rivers. Nor was there any attempt to demonstrate that afforestation of a watershed would lead to a noticeable decrease in the silt load. Instead, foresters were linking two or three potentially independent though simultaneously occurring events, and ascribing causality despite the absence of experimentation to support such a position.

H. H. Chapman, Professor at the Yale School of Forestry, made the case that overgrazing, and the resultant soil erosion, within the inter-mountain region of the country was leading to greatly increased flood damage.[41] The article received scathing criticism from a number of reviewers. J. C. Stevens, an Engineer, suggested that the Chapman gave the impression that

> ...millions of half-starved sheep and cattle [were] trampling each other in a frenzied search for the few sprigs of grass or sage still remaining on storm-gullied slopes, where but a generation ago was a cow's paradise of undulating hills protected from erosion by a veritable mat of succulent forage grasses.

> There is a silt problem, of course, as regards the filling of reservoirs, the maintenance of irrigation systems, and the loss of soil from cultivated fields, but grazing on the public domain has very little to do with it.
>
> I am just as heartily in favor of intelligent national control of grazing areas as of National Forests, but not for the reasons often given. There is every reason for such control from the standpoint of lumber supply, recreational and aesthetic gratification, and on grazing areas for the conservation of food for stock. I am, however, quite satiated with the 'no-forest-no-rivers' hoax and now the 'no-grazing-for-silt-control' campaign. By all means let us investigate the origins of silt and the means of its control, but let us do it in the name of science and not of political expediency.[42]

John F. Deeds, Chief of the Agricultural Division, U.S. Geological Survey was, equally dismissive of Chapman's assertions, pointing out that Champion failed to differentiate between naturally occurring erosion and accelerated erosion due to human activities. He suggested that Chapman's comments

> ... represent a likeness, true as to feature but exaggerated in detail – a cartoon, if you please – of the faithful and accurate delineation of conditions on the public domain. ... The article contains examples of excessive erosion ... and asserts that the 'only operative cause' thereof is overgrazing. The instances cited are not fairly or even approximately representative of average erosion conditions on the open public domain, and in even these extreme conditions there is no conclusive evidence of the amount of erosion attributable to man's activities.
>
> The article contains phrases pregnant with dire forebodings of disaster from erosion. To envisage any such disaster as a result of overgrazing on the open public domain seems to transcend the power of rational thinking.[43]

Others, including Benjamin E. Jones, Chief of the Power Division of the U.S. Geological Survey,[44] commented on the unsubstantiated assertions that grazing was responsible for increased erosion, increased flooding, and increased damage from flooding. Each of these rebuttals of Chapman's argument demonstrate, that in the absence of data establishing a causal relationship between grazing and erosion or flooding, there are plausible alternative explanations for Chapman's description of conditions in the mid-West.

The increasing interest in the U.S. during the 1920s and the 1930s coincided with the growing erosion concerns associated with Dust Bowl of the American mid-west. Although this latter was related to cultivation rather than grazing or deforestation, the dust-storms did bring to the fore the issue of the immense loss of fertile soil. The images of New York city being blanketed by soil blown in from Nevada were powerful enough to force the conclusion that something was seriously amiss. In general this was taken to be a symptom of the over-exploitation of nature, and that this had resulted in a significant disruption of the ecological balance, with Paul Sears' book *Deserts on the March*[45] predicting the

inevitable doom of American civilisation unless corrective action were taken to prevent such large scale loss of soil.

Foresters in various parts of the world had begun suggesting that the decline of ancient civilisations was directly related to the mismanagement of soil resources. Lowdermilk, famous for his work on erosion, stated that '[n]ot until recent years, beginning with George Marsh, has an inquiry been seriously made as to the part that mismanagement of soil has played in the decline or the destruction of a civilization, and the interrelation between civilization and erosion'.[46] Lowdermilk suggested that in arid hill regions, overgrazing by growing livestock populations had led to the destruction of vegetation cover. In the dry season, '... exposed soils ... were swept aloft and blown by the wind and in rainy season were washed down the slopes by torrential flows to ruin the fertility in the lowlands'.[47] Erosion, according to Lowdermilk, 'is a disease, difficult to discern at first, and responsive to treatment in the early stages, but absolutely fatal to civilization in its final stages'.[48]

Through the 1930s and into the 1940s, the U. S. Forest Service continued to highlight the role played by forests in controlling floods. In one report after another to Congress and the president, the Forest Service suggested that forest destruction was responsible for the continued damage from floods and that reforestation was necessary to reduce this flooding. And through it all the Forest Service failed continuously to substantiate its claims with data that could stand up to scientific scrutiny.[49] Engineers, in particular, were highly critical of the unscientific methods of the forest department.

> It is a sad commentary on a so-called scientific organisation like the Forest Service that during its existence it has never published a report on the role played by vegetal cover on the hydrologic cycle which was in accord with well-established hydrologic principles. In the history of that organization the hydraulic engineer or hydrologist engaged in experiments relating to the influence of vegetal cover on streamflow has been conspicuous by his absence...[50]

By the early 1940s, there were increasing demands that the Forest Service become more quantitative in its approach. And increasingly, the criticism came from within the service. At the Society of American Foresters annual meeting in 1939, E. A. Colman stated that he had looked at articles in the *Journal of Forestry* from 1936 through 1939, and found a number dealing with issues of forest influences. Most of them were qualitative. 'Is it not time we stopped rediscovering that vegetation prevents erosion and started finding out to what its protective influence can be attributed and to what extent it is effective?'[51]

By the 1950s a number of research stations had been set up to examine the relationship between forests and water and soil run-off. A number of them were paired experiments patterned after the Wagon Wheel Gap experiment in Colorado, conducted in the 1920s. Over the past four decades, these experiments have demonstrated a complicated relationship between forest cover, soil type, and

climate, in influencing the surface flow of water and soil, although for the most part, research appears to substantiate the broad conclusions arrived at by Bates in 1929. In general, the removal of forest cover leads to an increase in the flow of water from a watershed, owing to the decrease in the amount of water transpired by the vegetation. This increase does not take place in the form of enhanced flooding during the wet season, and reduced stream-flow during the dry season; rather there is a year-round increase in stream-flow, reflecting the fact that the increase has taken place owing to the reduction in transpiration, rather than an alteration in the storage capacity of the watershed.[52]

Results also demonstrate that the removal of forests do not of themselves increase soil erosion; rather it is the use the land is put to, following deforestation, that may lead to an increase in soil erosion. Logging roads completely denuded of vegetation were seen as a primary source of soil erosion. However, even under conditions of increased erosion, not all soil is washed out of the watershed. Rather, dislodged soil tends to get caught by uneven features of the landscape, such as depressions, vegetation, rocks, and so on, and that such soil can then become colonised by vegetation, thereby representing a transfer of soil within the watershed, rather than a loss of soil outside the watershed.[53]

To conclude this section on the ideas and practices within the American Forest Service, I refer once again to the analyses conducted by Schiff and by Dodds in the 1960s. Schiff suggests that a number of foresters probably preferred to continue with a qualitative rather than quantitative approach, simply owing to the uncertainty this generated. 'Possibly Munns favored for the time a program based on inadequate evidence, for continued uncertainty sustained faith in the potency of forest influences.'[54] This connection between ecological uncertainty and conservation rhetoric is a key argument I explore elsewhere.[55]

Schiff is perhaps over-zealous in his suggestion that all forester opinions stemmed from inter-agency conflicts. A more charitable evaluation may be that there was a great deal of variation within forester opinions, and that not all foresters were equally vehement in their comments on the protective role of vegetation. Fernow was a consistent dissenter in the cacophony of voices linking deforestation to the impending demise of American civilisation. Both Zon and Lowdermilk were also moderates, and at least within the scientific literature their assertions were often guarded. Zon in particular never tired of calling for better research in the understanding of forest influences on soil and water conservation.[56]

In similar vein, Dodds makes a number of telling comments in an insightful analysis of forester exaggeration of the protective role of forests.

> Pressed by their critics who were proposing the new quantitative methodology, the forestry advocates, some of whom were privately aware of their own methodological weaknesses, fell back upon enthusiasm and, on occasion, duplicity. Their commitment was to a cause, not to scientific evidence if the evidence contravened the cause. Nor was the stream flow struggle an isolated case of dogmatism.

> In the field of forest influences, where scientists even today are drawing only tentative conclusions from their experimental work, the conservationists were extremely slow to attempt controlled experiments and did so only in the crudest manner. Yet they argued for their cause as though its truth were irrefutable.[57]

The suggestion that conservationists have tended to work with issues of ecological degradation as if the evidence is beyond dispute has been commented upon by others, particularly in the context of degradation in east Africa.[58] And yet what comes through in this description is the complexity of the interactions between soils, water, climate and vegetation. It is important to note that the U.S. Forest Service has become more quantitative and experimental in its approach over the past four decades, although the agency remains embroiled in hotly contested issues, including grazing in the Mid-West, the spotted-owl controversy in the North-West and so on.

III. THE SCIENCE IN INDIAN FORESTRY

My analysis in this section is based on articles that appeared in the *Indian Forester,* the most widely read journal in India dealing with forestry and ecological issues during the late 19th and mid-20th centuries. My sampling of 76 articles in the *Indian Forester,* between 1875 and 1939, is based on a 54-page bibliography prepared by R. M. Gorrie, an Indian forester who was prominently involved in soil erosion issues in the mid-20th century. The document refers to almost 350 articles which appeared in a variety of international journals, though I have limited my selection to articles cited by Gorrie that appeared in the *IF.* In presenting this overview of literature on forest influences on hydrology and soils of the time, I have primarily attempted to demonstrate the international sources Indian foresters were drawing upon, the lack of local empirical research at the time, and the gradual transition from a diversity of views on the relationship between forests, climate and soil and water conservation during the late 19th and early 20th centuries, to a far more uniform, and generally alarmist discourse on the negative consequences of deforestation by the 1930s.

Late 19th century

Like their American counterparts, Indian foresters were greatly influenced by developments in European forestry during the late 19th century.[59] A number of articles of the time deal with the issue of forest cover and the loss of soil and water as a result of torrential streams originating within mountainous countryside. Baden-Powell, then Conservator of Forests, Punjab, suggested that the interest in the connections between mountain forest tracts, erosion, and flooding, could be traced to the extensive flooding in France in the mid-19th century and the

work of Surrel on the Torrents of the High Alps. Baden-Powell's descriptions of the consequences of the removal of forest cover from mountainous regions are classic examples of the descriptions that were to become common in the U.S. and India in later years.[60] A number of additional articles/notes written before the end of the century reiterated these concerns and arguments with regard to the destruction resulting from deforestation of the Hoshiarpur Siwaliks.[61]

Two other articles in the *Indian Forester* make more general comments regarding the role of forests in protecting the rivers of a country. One is about the Garonne river in southern France,[62] the other a more general treatise on flooding and the drying up of rivers, as a result of the deforestation of river catchments.[63] The latter is a rambling, anecdotal article, one that juxtaposes mythology, history and exaggeration, in a manner that is not altogether missing today. As an illustration of his point that deforestation was leading to a drying up of rivers, Cooper, a medical doctor, describes conditions in the Punjab:

> A telegram was but a few days ago received from India stating that 20 miles of railway were washed away in one night by flood waters in the Punjab, the result of but a few hours' rain. The word Punjab signifies 'the land of five rivers' – the Jhelum, the Chenab, the Ravi, the Beas, and the Sutlej, the last and southernmost of which was the limit of the expedition in ancient times of Alexander the Great. All these five rivers are silted up, and can hardly be said to hold water. The melancholy but impressive fact stares us in the face that there is scarcely a portion of any country in the world that is not now injuriously affected by its *normal* rainfall (emphasis in original).[64]

The suggestion that the five rivers 'can hardly be said to hold water,' is a likely exaggeration, considering that these rivers continue to be the primary source of water in the Indian and Pakistan Punjab. What is interesting, however, is the fact that the comment was made by a doctor speaking at the 'Royal Aquarium of the Balloon Society's Rooms', which suggests that the discourse was a part of a larger European discourse, linked to the growing concern regarding an imbalance being created in nature owing to the excessive utilisation of forest and other resources. The notion that excessive flooding, drought, famines and other environmental disasters were a reflection of a larger imbalance in the human-nature relationship pervades the writings of the mid- to late 19th century, and George Perkin Marsh's *Man and Nature* is a classic exemplar in this tradition.[65]

Not all writings in the *Indian Forester* published between 1877 and 1904, were unquestioning of the relationships between forests, rainfall, drought and flooding. In a lecture on the influences of the Indian monsoon, H. F. Blanford, Meteorological reporter to the Government of India, demonstrated that the geographic location of the Indian sub-continent played a key role in shaping the region's climate. Owing to the fact that the Himalayan mountains shield India from continental effects associated with the Asian continent, the monsoon is largely determined by the differential heating of the sea and the Indian land-mass, and the country's geographical location relative to the equator.[66] Blanford

did not deal with the forest question in this paper. However, in his memoirs, published in 1885, Blanford acknowledged the possible influence forests may have on rainfall, using data from three different parts of India to suggest such a relationship.[67] In 1889, however, the *Indian Forester* published a note saying that 'we are sorry to have to record that the figures used by Mr. Blanford are now proved to have been untrustworthy.'[68] Blanford had written to the Chief Commissioner of the Central Provinces, enquiring about the reliability of the data he had used, and the latter had pointed to likely inconsistencies in the data owing to differences in the types of rain-gauges used.

Two other papers relating to the U.S. also question the existence of any linkage between forests and rainfall.[69] Both point to the fact that the deforestation or afforestation of different parts of the U.S. had failed to alter cyclical patterns of rainfall over the past many decades. As John Lyman of New Hampshire wrote:

> In theory it seems true that one may shake the solar system by stamping upon the earth. Man may to a greater degree modify the climate and possibly affect the rainfall by his operations in agriculture and forestry, yet I fail to find proof of such supremacy over the subject as the many theorists claim.[70]

In a variation of a long-standing theme, Parquet suggested that although forests may not influence rainfall in a locality, the real value of forests lay in their ability to regulate the flow of waters, through the absorption of water and its slow release to springs and streams. As is demonstrated below, in subsequent iterations of these ideas Indian foresters backed off further to suggest that although such stream-flow regulation may not occur, forests *did* prevent surface run-off of both soil and water.

A series of articles in the *Indian Forester* in the late 19th century, examined the issue of forests and soil moisture in the context of data generated in Russia and in France. Experiments conducted in a number of locations by Ototzky, in Russia, suggested that the water table tended to be considerably lower under forested areas compared to adjoining deforested areas. The famous French forester, Henri, replicated these studies in France and arrived at similar conclusions, thereby questioning the basic notion that forests acted as giant sponges. The experiments indicated that forests consumed rather than conserved water, an observation that would, of course corroborate the well known phenomenon of the time that 'forest vegetation has a remarkable faculty for drying up and draining marshy plots'.[71]

A number of articles attempted to explain these results away by suggesting that the high degree of evapotranspiration by these forests led to much enhanced moisture in the atmosphere, and hence, higher rates of precipitation; that the value of the forests lay not in the amount of water that was made available (since so much of it was transpired) but rather in the regulation of stream-flow; and that the mountain forests in particular played a critical role in slowing the surface flow of water.[72]

Two issues are of interest in the above section. First, Indian foresters made more frequent reference to the European, rather than American forestry literature, which was still in its infancy at the time. Second, there was a diversity of opinions within the European forestry tradition regarding the relationship between forests and water. Particularly striking is the fact that even during the late 19th century, there was a clear articulation of the fact that forests acted as pumps rather than as sponges. The validity of the idea was consistently resisted within the American Forest Service until well into the 1930s, and the notion of forests acting as sponges continues to drive forester conception of forest functioning in India today.

Early 20th century

In 1908 John Nisbet, retired Conservator of Forests, pointed out that the incidence of famine had greatly increased in India over the past half century, and he attributed the increase to recent deforestation.[73] The same year, Nisbet wrote to the Secretary of State, regarding the seriousness of the situation. In response, an enquiry was initiated across the country to determine the relationship between forests and atmospheric and soil moisture. As part of the enquiry, a questionnaire was widely circulated among government officials, including meteorologists, geologists, foresters, and district administrators. Their opinions were requested mainly on two issues: the connection between forest cover and rainfall, and the connection between forest cover and soil and water conservation. With regard to the first, there appeared no information from any part of the country to suggest any permanent change in rainfall patterns over the past fifty years or so, despite the evidence for considerable deforestation.[74]

With regard to change in the water-table, there was consensus from around the country that '... in the absence of reliable data lasting over a prolonged period, it could not be said whether there had been any permanent change in the level of the underground water-table; generally speaking, it appeared that the level depended on the rainfall and varied directly with it'.[75] The report's conclusion with regard to the relationship between forests and stream-flow was that '... generally speaking, it could not be said that the flow of rivers and streams was less equable, that floods were shorter in duration and more violent, and that streams dried up more quickly'.[76] With regard to the relationship between deforestation and soil loss, the report makes the comment that '...the denudation of the soil, owing to the destruction of forests, might as far as India is concerned, be looked upon as an established fact'.[77] Much of the basis for the last comment came from the responses of officials in the Punjab, pointing to the destruction of forests in the Siwalik mountains. These mountains are naturally erosive, owing to their geologic structure and composition. Extrapolating from the Siwaliks to the rest of the Punjab is problematic, the extrapolation to the rest of the country even more so.[78]

A number of articles were published in the *Indian Forester,* following the enquiry and these are interesting for a variety of reasons. Of thirteen articles published by the Indian Forester between 1906 and 1911, on the connection between forests and rainfall, nine have references to European research, one to American research and one to a comment made by President Roosevelt. Second, there appears to have been a general lack of consensus regarding the role forests played in enhancing rainfall. W. L. Moore's landmark paper, which argued that forests did not influence rainfall and did not regulate flood waters, was reviewed in the *Indian Forester* in 1911. For the most part the reviewer dismissed the arguments made by Moore, using the hostile reaction Moore's paper received in the pages of *American Forestry* to substantiate his own case.[79]

Third, and contrary to the findings of the survey, there was general agreement that forests played a critical role in water conservation, through storage of water and the more equitable release of water through the year. However, in an interesting departure from a key prediction of such a model, Pearson demonstrated that ground water under forested lands was considerably lower than ground water in lands without forest cover. Following up on Ototzky's and Henri's research, Pearson measured water levels at different times of the year in wells located within and outside forested areas, eventually demonstrating that on average well water within the forest was 11.45 metres below the surface, while that outside forests was 6.71 metres below the surface. Pearson explained the results away by suggesting that even though there was such a difference, there was much less variation in the water level in the forest condition than in the non-forest condition, although his data does not support such a conclusion.[80]

The validity of this use of wells to detect differences in water under areas with differing amounts of forest cover was generally rejected even before the publication of the results of the ongoing country-wide survey.

> We may take it then that well measurements are not at all to be depended on for accurate deductions. At the same time any one acquainted with the laws of water subsoil storage, and its guiding principles will hardly deem it worth while to argue that forest growth does not have a beneficent effect in this direction.[81]

In general, in anticipating the results of the survey the author appears to be criticising its lack of rigour, and he also points to multiple linkage relationships that would prevent the generation of information that would specifically demonstrate a connection between forests and rainfall or forests and water storage. And, as is illustrated in the above quote, the author resorts to the well worn technique of claiming a fact to be too well known to be worth the investigation.

Two articles in the years immediately following the publication of the enquiry made reference to the report – the first suggesting that the report was simply an affirmation of the popular view that forests played a critical role in soil and water conservation;[82] and the second suggesting that the Government's money may have been better spent in appointing a scientist to submit a report

based on real data, rather than just the subjective opinions of a number of district officials.[83]

By the 1920s Indian foresters were drawing increasingly on the writings of their American counterparts to substantiate their own ideas. In 1921, the *Indian Forester* reprinted an article by Raphael Zon, Chief of Research with the U.S. Forest Service, reviewing the Emmenthal experiments in Switzerland. In acknowledging the finding that forest cover need not aid in the retention of water, Zon suggested that the real value of the study was in the demonstration that forest cover ensured a more regular sub-surface water flow, when compared with unforested conditions. This effect was apparently linked to the porosity of the soil, 'brought about by the protection afforded by the tree crowns, by the formation of leaf mould, and by the presence of living and dead roots and an abundant soil fauna.'[84] Whether Zon is simply providing an explanation for what he perceives to be a widely held phenomenon – that forests regulate stream-flow – or whether this last comment is based on the experiment is unclear.

Two articles published in the *Indian Forester* were highly sceptical of the Wagon Wheel Gap Experiment in Colorado, described in the previous section. The first, in 1922, following the publication of the data from the first phase of the experiment, suggested that 'it is a little difficult to place implicit confidence in either the precipitation statistics or the use that is made of them. Though details are, perhaps significantly, lacking, it is evident that the exposure of the gauges for rain and snow is not up to the standard required in this country, while their distribution also leaves something to be required.'[85] The bulk of the article is similarly dismissive of the rigour with which the experiment was being conducted, although such criticism was not levelled against the experiment within the U.S.

In the second article, published in 1928, H. G. Champion reviewed the results of the second phase of the Wagon Wheel Gap experiment, stating the basic findings, which included the fact that stream run off was greater from the watershed following deforestation, the increase took place throughout the year, rather than in the form of a flash flood, and that there was no increase in erosion following the deforestation. Champion goes on to downplay the importance of the study, suggesting that owing to the high elevation and the low rainfall at the study site, the results of the study were only of local interest, and certainly of little value to Indian foresters. He also stated that it was 'a pity all this labour was not expended on an area where the matters under investigation – erosion and run-off – were to be anticipated as active to a greater degree.'[86] Champion appeared unwilling to accept the theoretical point that was being made, i.e. that the removal of forest cover did not necessarily increase soil or water run-off. Champion's comment that the study had little relevance to the Indian context is also problematic considering the considerable fuss that foresters were making with regard to the consequences of deforestation and overgrazing in the Himalaya.

Closely following these publications, E. Benskin reported results from his own experimentation in the Chota Nagpur region, in Central India, showing that (i) 'leaf litter which annually falls in the case of first quality sal forests, is capable of absorbing slightly less than .03 inches of rain, and that the theory that forests control stream-flow by means of the absorbing power of the litter certainly did not apply to Chota Nagpur';[87] (ii) that soil moisture was much greater in denuded rather than forested areas, a result that had now been arrived at by a number of investigators; and (iii) 'that grass, if left ungrazed and uncut during the monsoon, has an effect on stream-flow considerably greater than forests.'[88]

The above results were at great variance with some of the other writing of the time. Reminiscent of earlier writings, and seemingly oblivious to the larger debate taking place within the *Indian Forester* and within the U.S. and in Europe, an anonymous article goes to great length to make the point that deforestation in mountainous regions leads to excessive flooding and soil erosion.

> The great factor in mountainous and hilly country is the maintenance of tree growth on parts of the area. In the case of bare slopes the rain rushes rapidly down, causing erosion, only a fraction percolating into the soil, and is carried rapidly away, giving rise to spates and perhaps serious floods, since the old channels of these streams or rivers are no longer able to carry the excess water of flood waters.... In the hotter parts of the globe subject to heavy rainstorms or monsoons the rushing water starts gullies, which eventually become ravines, all surface soil is rapidly washed away, and in the course of years the hillsides is eaten into, rubble and boulders being sent down to cover up valuable lands below.[89]

The writings of the first three decades of the 20th century show a remarkable transition with regard the two central issues I am dealing with: first, during this period Indian foresters made more frequent reference to American events and writings than they did to developments in European forestry; and second, there continued to be a considerable array of viewpoints within the writings in the *Indian Forester* regarding the connections between forests and soil and water conservation, a diversity that was to decline sharply in the following decade.

The 1930s and on

Gorrie's bibliography, upon which this analysis of scientific writing is based, has over 150 articles for the decade following 1931 dealing with the issue of soil erosion, climate, water regimes and their various connections to forest cover, almost half as many as he reported published in the five preceding decades. Over 40 of these were published in the *Indian Forester*. The papers do not display a similar breadth of view points that writings in earlier periods do. A large number of these papers take generally alarmist standpoints, supported by little, if any experimental data, while only the occasional paper, such as one written by W.

C. Lowdermilk, Vice-Director, Soil Erosion Service, U.S. Department of Interior, points to the complexity of forest, soil, and vegetation interactions.[90]

Erosion and flooding in the Punjab continued to be a major focus of these articles, and Gorrie's familiarity with the Punjab literature may have biased his compilation of the bibliography. In each of these papers there is a repetition of the same story-line again and again – the over-exploitation of the region by a growing population, leading to deforestation, the beating of the rain on exposed soil, the formation of gullies leading to a directed increase in the force of water flowing off the hillside, in the process carrying with it soil and boulders, leading both to the decline in the productivity of the hillside itself, as well as to the destruction of fertile fields in the flood plain of the torrents formed higher up.[91] Few of these authors demonstrate an experimental link between these various phenomenon. There is no data to support the idea that the human and livestock population was growing, although assuming that to be the case is reasonable. More importantly, however, there was no attempt to demonstrate that livestock grazing was in fact leading to overgrazing; nor was there an attempt to demonstrate what constitutes overgrazing for different vegetation types. Rather overgrazing was taken to mean the complete removal of vegetation cover, which in the presence of the hordes of sheep and goats, had no chance of recovering. There was no attempt to demonstrate that the first rains during the monsoon were of such intensity that they do, in fact, remove large amounts of soil. There was no attempt to examine what happened to soil dislodged from a particular place – rather there was the assumption that once dislodged, the soil was permanently lost to the flood. And finally, there was no attempt to differentiate naturally occurring erosion from accelerated erosion.

The only experimentation that one comes across during this period is some work by Gorrie himself, in which he designs an experimental set up based on work done by Lowdermilk in the U.S.[92] The experimental design comprised a number of trays of soil, set at varying slopes, with varying degrees of vegetation cover, set out in the open, and hence exposed to rainfall, with a complicated mechanism for collecting and measuring soil and water at the end of each tray. Lowdermilk and Gorrie reported extremely high levels of soil loss from these set-ups. The artificial nature of these situations poses a problem with regard to the applicability of such data, particularly with regard to the extrapolation of data from a soil tank 'ten square feet in area and 2.5 feet deep', to an entire watershed.[93]

In an influential paper, Holland and Glover, senior officials with the Punjab Forest Service make the point that the intensity of flooding in the Punjab had increased in recent years:

> It appears that floods are greater now than formerly, and now that the waters of the Punjab are being utilised to their full capacity, are likely to be greater in their

> economic effects. We may take it as axiomatic that the intensity of floods is rendered greater by the disappearance of forests.[94]

The authors do not demonstrate that there has been an increase in flooding intensity, and follow that up with the unsubstantiated statement that the increased flooding is due to the removal of forest cover. As outlined above, plenty of research had begun to question such a simplistic relationship – an issue to which Holland and Glover make no reference whatsoever.

The primary concern of the Holland and Glover article is with the devastation taking place in the Siwalik mountains of the Punjab. 'In the outer Himalaya, conditions are very bad indeed: the forests have largely disappeared and all vegetation in the village waste is subject to very heavy grazing by both local and migratory flocks which are slowly but surely destroying all tree and bush growth.'[95] A reading of a note by Baden-Powell in 1879, demonstrates little change in conditions over a period of six decades. Baden-Powell had described the Siwaliks in the following terms:

> But so great has been the destruction that one may march for miles and miles with nothing in view, but bare, mud-coloured crests and rugged slopes, rarely dotted with greyish browsed-down bushes, while an occasional 'kikar' bush that has sprung up out of reach is alone green and flourishing. Herds of hungry goats reaching up for the last living twigs or the ill-used stumps of trees, may everywhere be seen. Nothing is more striking that the general bare, pale-brown or dust-coloured aspect of the landscape for miles together in these hills.[96]

Buried in this consistent description of bleakness combined with the exploding human, goat, and sheep population in the region, is the biological improbability that a barren land would allow such an explosion to take place. By definition human and animal population growth cannot outstrip the vegetation and fuel it is dependent upon for fifty years, the period that separates these two articles.

Having first made the assumption that forests regulate stream-flow, and then provided a description of the heavy livestock pressures reducing forest cover, Holland and Glover proceed to combine the two to demonstrate the consequences of such misuse of the land.

> '[O]n the Siwalik formation of friable sandstones and pebble beds the disappearance of the forest cover is immediately followed by deep erosion and the formation of ravines; the streams carry thousands of tons of sand and sediment to great distances and have frequently destroyed large areas of fertile land in the plains.'[97]

I have dealt with the Holland and Glover paper in such detail owing to the fact that it is subsequently quoted by numerous foresters in making a case regarding the destruction taking place within the region. Two issues stand out. The first relates to the fact that the paper was presented at the Association of Indian Engineers. Judging by the reactions of the editors of *Indian Engineering*, where it was first printed, the paper was well received by the engineering community.

Partly based on this reaction, I am led to believe that engineering opposition to forester policies was inconsequential in comparison with engineer opposition within the U.S. Second, any suggestion that the obvious exaggerations in the Holland and Glover paper in 1930 are simply a reflection of the thinking current at the time is problematic given the research of the 1920s that was pointing to a far more complicated relationship between forests and soil and water conservation. Over the course of the 1930s and 1940s, this disjunction between rhetoric and scientific data was to become increasingly pronounced.

In the early 1930s there was still some level of questioning of the more extreme position with regard to the benefits conferred by forests. Six months after the Holland and Glover paper was published, a review paper appeared in *Nature*, reprinted in the *Indian Forester*.[98] The article reviewed five major recent studies, and suggested that there was growing conviction that forests played little role in influencing climate – while it was generally accepted that forests played a critical role in soil conservation. Importantly, the article pointed to the fact that past debates within international forestry had been based more on generalisations and less on data.

> [I]t is due to the fact that so much theory has been indulged in and so much written that would not bear either scientific analysis or ... such practical field tests as were feasible, that has led to this question being neglected in the past – in fact, it might even be added, to the question being treated with derision by a certain type of forest officer, by the public, and by the civil authorities.[99]

During the early thirties, more active dissent was also articulated by a forester in connection with the ability of forests to prevent floods. Writing in *Indian Engineering,* Ryan discounted the notion of forests having anything to do with recent flooding in the Punjab, suggesting instead that bad embankment practices had been primarily responsible for the trouble. Ryan basically held that close embankments did not give rivers the space they needed to overflow - and that, instead of gradually flooding a once uninhabited flood plain, close embanking was leading to a greater and greater build-up of energy, which upon bursting through the embankments, would tear through a densely settled floodplain. Thus, while the damage from floods could be considerably greater than before, the frequency of floods was not necessarily increasing.[100]

In response to Ryan's article, the editors of *Indian Engineering* pointed out that while close embankments may be a part of the problem, the crux of the problem lay in deforestation, and the resultant soil erosion that accompanied such deforestation. They allude to the massive soil erosion taking place in the watersheds of the Mississippi and the Yellow and Yang-tse-Kiang rivers to support their argument, going so far as to suggest that

> the latter alone is said to carry suspended material to the sea to the volume of 6,428,858,255 cubic feet annually, and, with the Pei Ho added, it has been calculated that the three would in sixty days form an island a mile square in the sea. In 1887 the

> Yellow River, breaching its embankments, destroyed 3,000 villages and the depopulation was put at from two to seven millions of people.... But a bad embankment system does not add to the volume of water brought down...[101]

The basis for these calculations is unclear. However, the use of such figures lent considerable weight to an argument regarding the seriousness of the whole issue, if for no other reason than the enormity of the suggestion that over six billion tons of soil were being carted to the sea every year, by the Yang-tse-Kiang alone. Such figures make a number of appearances in the *Indian Forester* throughout the 1930s and after. Within the Indian context, for example, Smythies pointed to the massive loss of soil as a result of ongoing erosion in the Chambal ravines, in the United Provinces.

> In the Jumna Chambal basin, for example, between a quarter and a half million acres of land have had 20 to 40 feet depth of soil eroded. *This represents the loss of a perpetual stream of soil, never stopping for an instant, day or night, removing over 12 cusecs or half a ton per second for the past 1,000 years* (emphasis in original).[102]

That soil erosion was a growing concern is also apparent from the fact that the Punjab Erosion Committee was formed in 1932, and a Punjab Erosion Conference convened in 1936.[103] Gorrie outlines some of the chief discussions at the conference, including measures taken in the Hoshiarpur Siwaliks to curb overgrazing, results from which had been 'most satisfactory'. Conditions in Kangra district, however, were particularly bad, and the 'process of denudation of grazing lands is already a good 50 years further ahead in Kangra than it is in Kumaon.'[104] Similarly, with regard to the Uhl Valley and the Jogindernagar Power Plant, he says that 'the position is by no means hopeless and can be saved, provided strong action is taken in arresting further denudation...'[105]

By the late 1930s and 1940s, three influential foresters were making repeated references to erosion and desiccation in India – R. M. Gorrie, E. P. Stebbing, and E. A. Smythies. Both Smythies and Stebbing used examples from around the world to suggest that over-exploitation of forest resources was leading to a continual process of desiccation. The American Dust Bowl and the flooding in the Mississippi were cited by both as classic examples of the consequences of such over-exploitation; so too was the southward movement of the Saharan Desert,[106] 'a mile a year' according to Smythies.[107] Both Stebbing and Smythies suggested that firing, over-cultivation, and nomadic pastoralism were responsible for the deplorable state of affairs.

Smythies went on to talk about erosion in the Indian context.

> Many years ago it had been clearly proved and recognised as a universal phenomenon that destruction of forest growth in a mountain country, without compensation such as terracing and regular cultivation, led to a tremendous increase of erosion, avalanches, destructive floods, drying up of water springs, over burdening the rivers with silt and boulders. Where the rivers debouched on the plains, this burden of

> detritus is deposited far and wide over fertile cultivation, wiping out whole villages and towns, silting up canals and even mighty Empires have crumbled before the irresistible advance of man-made deserts and sheet erosion. Thus the change of the once fertile lands of Mesopotamia into desert has been widely ascribed by many authorities to the destruction of the natural vegetation by man and his cattle, while the ruination of hundreds of villages in the Hoshiarpur district of the Punjab, due to the destruction of the forests, in the adjoining hills, is a well known phenomenon.[108]

Such reporting is more in the realm of fantasy, than objective science. While the processes described above may occur over isolated areas, such as around a watering hole, to suggest that the major deserts of the world have been formed due to human intervention is problematic. There is little basis to such speculation; rather there is the presumption that all desert lands were formerly more forested and less arid. The account also discounts any possibility of a climatic event effecting such a change.

In 1948, Gorrie, writing in *The Geographical Review*, published by the American Geographical Society, introduced a new dimension to the issue of desertification in the Punjab, suggesting that the Great Indian Desert was extending northward into the fertile lands of the Punjab.[109] Concerns over this advance, led until the 1980s, to the planting of shelter-belts, although the general hysteria of a decade ago appears to have now passed.

As a final example of the alarmist writings of the time, B. S. Sitholey wrote the following for the *Indian Forester* in 1949.

> Where not due to other causes the decline of the great centres of ancient civilisation revealed to us by archaeologists was in all probability the result of erosion of the surrounding land. It is inconceivable that such cities were built and flourished upon the sand that now covers them. ... Mohenjodaro Sindh is a case in point. ... Only the ultimate sterilisation of the land and consequent total failure of the crops must have left no alternative to the people but to move out: erosion was thus responsible for the extinction of the earliest known civilisation in India.[110]

While references to the impending collapse of Indian civilisation faded with time, the notion that forests were an integral component of a flood control program continues to influence flood control policy in India. Following the 1978 floods in the Yamuna river, K. M. Tiwari, President, Forest Research Institute and College, Dehra Dun, wrote a report on how best to control these floods.[111] As part of his analysis, Tiwari stated that since there had not been an abnormal increase in rainfall in the region, the only explanation for the heavy flooding lay in the manner in which water was being drained or the decreased capacity of the watershed to retain adequate water.

> Moreover, the water retaining capacity of most of the existing forests has materially gone down in the last 2-3 decades.... Fellings have increased in the hilly areas due to opening up of the interior areas through a net work of motorable roads. Large scale

> fellings are being done every year in the civil forests which are not managed by the forest department, without any plan of reforestation. The forests are being subjected to much higher incidence of grazing than ever before due to tremendous increase in cattle population. All these adverse factors have cumulative effect of reducing the water holding capacity of the area concerned, increasing the run-off and accelerating the erosion of soil leading to sedimentation of the river beds down below.[112]

That this rhetoric had long since moved beyond merely being a product of the Forest-Revenue Department conflict in the Punjab, is illustrated by the fact that Gorrie was publishing these ideas in the prestigious Geographical Review. And yet, by the 1940s and 1950s, few American foresters were making similarly alarmist predictions with regard to the U.S. itself. In a sense the discourse had moved out of academic journals and into the popular domain, where it remains to this day. Unfortunately, such understanding continues to drive policy formulation within the areas that were formerly key exemplars of the effects of the desiccationist discourse – in particular sub-Saharan Africa and the Himalayan mountains.

IV. CONCLUSION

A key objective of this essay has been to explore the international progression of ideas regarding the climatic and protective capabilities of forests during the late 19 and mid-20th centuries. In doing so I have attempted to counter the current understanding that European thinking has had an over-arching influence on Indian forest policy formulation.[113] Instead, I have argued here that the roots of the current desiccationist discourse are, at least partly, to be found in the bureaucratic conflict that took place within the U.S. in the early to mid 20th century. The conflict between the Forest Service and the Army Corps of Engineers over issues of flood control, resulted in certain foresters greatly exaggerating the protective value of forests. At various points in time, officials of the American Forest Service indicated that forests could increase rainfall, moderate temperature extremes, control floods, ensure an even, maximised, stream-flow throughout the year, and prevent the loss of valuable soil. Many of the theoretical underpinnings to each of these claims were called into question by empirical research initiated in the early 20th century. In turn, much of this research took place as a result of repeatedly articulated scepticism on part of meteorologists, geologists and engineers.

Indian foresters used, and contributed to, this desiccationist discourse. An article written by E. P. Stebbing in 1935, is considered by researchers of East African range lands south of the Sahara, to be responsible for initiating the widespread acceptance of the notion of the southward advance of the Saharan Desert.[114] At the same time, Indian and African foresters routinely used writings

of American foresters such as Lowdermilk, and soil scientists such as Bennett, to advance their claims regarding the desiccating influences of excessive grazing. Unlike the late 19th and early 20th centuries, when Indian foresters used European research to substantiate their own ideas, by the 1930s the sources used by Indian foresters were almost exclusively American.[115] And for this reason, it is important to understand the American institutional context within which conservation ideas were being formulated, a context I have outlined in this essay.

Having said this, however, it must also be pointed out that Indian foresters did very specific things to provide coherence to the models of forest functioning that they described in their popular and professional writings. First, foresters were highly selective in their use of evidence to advance their arguments. For example, foresters often used the most glaring examples of soil erosion to substantiate their arguments regarding the damaging effects of the removal of vegetation, as can be seen from the frequent references to the American Bad Lands, the Grand Canyon, the highly erosive Loess mountains of Northern China, the Hoshiarpur Siwaliks, and the Chumbal ravines in Central India. In each of these instances, an assumption was made that forest cover over these areas must have been extensive in former times, and that their current barren, ravine like conditions, were entirely due to the removal of this vegetation. An equally plausible explanation would be that climatic conditions and/or the inherent looseness of the soil, had always precluded the establishment of heavy forest cover. Soil losses may historically have been high.

In all of this, foresters were simplifying the inherent complexity of ecological interactions, thereby enabling a fit between their own theories and an observable phenomenon. The suggestion that all human land use led to deforestation and that this deforestation had specific, predictable results, irrespective of the range of physical conditions under consideration, is a classic example of such simplification. Foresters could point to all sorts of calamities to assert the importance of forests – the collapse of earlier civilisations, obviously high levels of soil erosion in the Hoshiarpur Siwaliks, the American Bad Lands, and so on. In each of these instances foresters could use the irrefutable facts of history, in conjunction with a specific model of how nature worked, to 'prove' the correctness of their model, and thereby the potentially disastrous consequences of any further reduction in forest cover.

There is an obvious problem with such a fitting of facts to theory, which is that the theory may be wrong, and that an altogether different set of environmental processes may have led to the conditions used by foresters to justify their own models. Separating such co-variation from causality has always complicated our understanding of ecological phenomenon. The continuing lack of consensus regarding the ecological impact of grazing in the region attests to the complexity of the issue (see debate in *Conservation Biology*, September, 1994).

A distorted understanding of forest functioning was common to forest services in different parts of the world during the 1930s, and one would be hard

pressed to argue the case that this discourse had its origins in interagency conflicts in the Punjab, the U.S., or elsewhere. What is noticeable, however, and perhaps attributable to such conflicts, is the manner in which leading foresters of the time projected the desiccating discourse during the 1930s and 1940s. In effect, the diversity of views that existed on the subject during the early part of the 20th century was rarely referred to in the debates of the 1930s and 1940s. It is in this 'shaping' of the discourse, that opposition to institutionalised conservation is likely to have played its most significant role.[116]

Such selective pressure can be seen in other instances of ecological thought as well. Between the 1950s and the early 1980s, a continuous stream of studies documented patterns in a wide range of habitats, patterns that could plausibly be explained in terms of the dominant paradigm in ecology: the equilibrial nature of system functioning, and the role of competition in maintaining this equilibrium. None of this work was based on experimental manipulation that would allow the testing of causal relationships. Rather it was based on the documentation of patterns, the fitting of these patterns to well-established expectations of how nature functioned, and the assigning of causation to a specific interaction within nature. The question of what structures natural communities is complicated by the fact that competition, predation, and parasitism, along with both climatic and anthropogenic disturbances may be occurring simultaneously. The failure to use appropriately designed experimental setups, testing for specific relationships, resulted in the failure to establish causation in the competition studies of the 1960s and 1970s, an issue that has received considerable attention since the late 1970s.[117] Worster links the assumption of an inherent balance to nature, one maintained by competitive forces, to Christian mythology that sees nature as being of divine creation within which each species has its appointed place. Theoretical community ecology in this case, has laboured long and hard to sustain this cultural construction of the natural world.[118]

A final issue of interest is that while alarmist positions within American forestry gradually gave way to a more quantified approach, an alarmist, anecdotal style continued to drive forest policy in India, and, for that matter in much of Africa. That current forester conception of the functioning of forests in the U.S. and in India is based on two radically different models, one based on experimental data, the other on the weight of historical debate, may in some measure be attributed to the different receptions forester proclamations received in the U.S. and in India during the early 20th century. Demands by the engineering, meteorological, and geological communities for more rigorous work by foresters, ultimately forced the U.S. Forest Service to become more quantified in their approach. In a sense, then, the opposition from these other groups was initially responsible for the exaggerated discourse within the U.S., but also eventually, for the increasingly quantified approach now used by the American Forest Service.

In contrast, there was little opposition to the proclamations of the Indian Forest Service from professionals in other scientific fields – such as in engineering, meteorology and geology. During the All Indian Survey of the protective and climatic functions of forests, meteorologist and irrigation engineers had dismissed the idea that increasing deforestation was having any influence on either rainfall or flooding patterns. For some reason, however, opposition from these quarters is not in evidence in the following years. Instead, the Forest Department was faced with a great deal of opposition from the Revenue Department, opposition based on political, rather than scientific reasons and Commissioners and Deputy Commissioners lacked the training to question the scientific rigor of the beliefs of Indian foresters. As a result, the continued opposition by the Revenue Department simply drove the Forest Department to a greater and greater use of an alarmist, and from the Forest Department's perspective, politically valuable, rhetoric. Through a selective reporting of scientific developments in the U.S., Indian foresters were able to portray potentially disastrous environmental situations in the making – scenarios that the Revenue Department and the British government was forced to take cognisance of simply owing to the potential political fallout of such disasters.

NOTES

The material presented above is culled primarily from Chapter 7 of my Ph.D. dissertation. I am grateful to the Himachal Pradesh Forest Department for logistical support while I conducted this study. For assistance in locating sources, I am grateful to the staff of many libraries and archives, including the National Archives in New Delhi, the Himachal Pradesh State Archives in Simla, the India Office Library in London, and the Forestry and Seely Mudd libraries at Yale University. Financial support was provided by the Biodiversity Support Program (a consortium of World Wildlife Fund, The Nature Conservancy, and the World Resources Institute, with funding by the U.S. Agency for International Development), the Yale Center for International and Area Studies, the Agrarian Studies Program at Yale University, and the American Institute of Indian Studies. This essay was written while I was a Fellow at the Pacific Basin Research Center, of Soka University. During this time I was provided administrative support at the Harvard Center for Population and Development Studies, for which I am grateful. Conversations with Paul Barton, Bill Burch, Jane Coppock, Joe Miller, Nancy Peluso, Oswald Schmitz, Krys Stave, and K. Sivaramakrishnan, and comments from some of the above on earlier drafts, have served to tighten the writing and thinking presented here. In particular, Joe Miller was generous in sharing sources and ideas and he took a considerable interest in the work. Joe succumbed to cancer earlier this year, a tragic loss for the many who knew and worked with him. This paper is dedicated to his memory.

[1] Eckholm, E. 1977. Spreading deserts: the hand of man. Worldwatch paper no. 13. Washington, D.C. Quoted in Hellden, U. 1988. Desertification monitoring: is the desert encroaching? *Desertification Control Bulletin* 17: 8.

[2] Olsson, K. 1984. Long-term changes in the woody vegetation in northern Kordofan, Sudan. Lunds Universitets Naturgeografiska Institution, Sweden, in cooperation with the Institute of Environmental Studies, University of Khartoum, Sudan. Quoted in Binns, T. 1990. Is desertification a myth? *Geography* 75: 109.

[3] A selection of the recent literature that has critiqued earlier thinking with regard to land degradation includes: Sandford S. 1983. *Management of pastoral development in the Third World.* John Wiley and Sons, Chichester; Hamilton, L. 1987. What are the impacts of Himalayan deforestation on the Ganges-Brahmaputra lowlands and delta? Assumptions and facts. *Mountain Research and Development* 7: 256-263; Homewood, K. and A. W. Rogers. 1987. Pastoralism, conservation and the overgrazing controversy, in D. Anderson and R. Grove (eds) *Conservation in Africa: people, policies and practice.* Cambridge University Press, Cambridge, pp. 111-128; Ellis, J. E. and D. M. Swift. 1988. Stability of African pastoral ecosystems: alternate paradigms and implications for development. *Journal of Range Management* 41: 450-459; Ives, J. D. and B. Messerli. 1989. *The Himalaya dilemma: reconciling development and conservation.* Routledge, New York; Abel, N. O. J. and P. Blaikie. 1990. Land degradation, stocking rates and conservation policies in the communal rangelands of Botswana and Zimbabwe. Pastoral Development Network Paper 29a, Overseas Development Institute, London; Binns, T. 1990. Is desertification a myth? *Geography* 75: 106-113; Agarwal, A. and A. Chak. 1991. Floods, flood plains and environmental myths. State of India's environment: a citizen's report, # 3. Centre for Science and Environment, New Delhi; Tucker, C. J., H. Dregne, and W. Newcomb. 1991. Expansion and contraction of the Sahara desert from 1980 to 1990. *Science* 253: 299-30; Behnke, R. and I. Scoones. 1993. Rethinking range ecology: implications for rangeland management in Africa. IIED, London; Saberwal, V. K. 1998. *Pastoral politics: shepherds, bureaucrats, and conservation in the Western Himalaya.* Oxford University Press, New Delhi.

[4] Hilborn, R. and D. Ludwig. 1993. The limits of applied ecological research. *Ecological Applications* 3: 550-552.

[5] See for example, Grazing Advisory Committee. 1972. Report of the Grazing Advisory Committee on the grazing policy of Himachal Pradesh, Simla, Himachal Pradesh. The report continues to form the basis for the grazing policy of the government of Himachal Pradesh in Northern India. See also, Eckholm, E. 1975. The deterioration of mountain environments. *Science* 189: 764-770; Eckholm, E. 1977. *op. cit.*; Lamprey, H. F. 1983. Pastoralism yesterday and today: the overgrazing problem, in F. Bourliere (ed.) *Ecosystems of the World 13, Tropical Savannas*. Elsevier, Amsterdam, pp.643-666; Myers, N. 1986. Environmental repercussions of deforestation in the Himalaya. *Journal of World Forest Resource Management* 2: 63-72.

[6] Myers, N. 1986. *op. cit.* pp. 64-66, emphasis added.

[7] While subsistence land-usage may indeed have significant consequences with regard to the capacity of the land to support current demands for grazing, fuelwood, and timber resources, they are unlikely to have the predicted disruptive impact on the region's hydrological regimes. See Hamilton, L. 1987. *op. cit.*; Ives, J., and B. Messerli. 1989. *op. cit.*; Agarwal, A. and A. Chak. 1991. *op. cit.*

[8] Bosch, J. M. and J. D. Hewlett. 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. *Journal of Hydrology* 55: 3-23.

[9] Saberwal, V. K. 1997. Bureaucratic agendas and conservation policy in Himachal Pradesh, 1865-1994. *Indian Economic and Social History Review* 34: 465-498; Saberwal, V. K. 1998. *op. cit.*

[10] It is important to note that I am not suggesting an absence of land degradation resulting from cultivator or herder use of forest resources. Rather, I am pointing to the prevalence of an overly alarmist rhetoric on degradation, one that has been used time and again to justify the imposition of policies that exclude local communities from areas they have traditionally had access to. Such policies have often initiated spirals of social and economic decline. See for example Anderson, D. and R. Grove (eds) 1987. *Conservation in Africa: people, policies and practice.* Cambridge University Press, Cambridge; Hogg, R. 1987. Development in northern Kenya: drought, desertification and food scarcity. *African Affairs* 86: 47-58; Little, P. D. 1991. *The elusive granary: herder, farmer and state in Northern Kenya.* Cambridge University Press, Cambridge.

[11] For the former position see Guha, R. 1989. *The unquiet woods: ecological change and peasant resistance in the Indian Himalaya.* Oxford University Press, New Delhi; for the latter, see Rajan, R. S. 1994. Imperial environmentalism: the agendas and ideologies of natural resource management in British Colonial forestry, 1800-1950. Ph.D. Dissertation, University of Oxford, Oxford; Grove, R. 1995. *Green imperialism: colonial expansion, tropical islands, and the origins of environmentalism 1600-1860.* Oxford University Press, New Delhi. For a more nuanced discussion of policy formulation and particularly the influence of the local experience on the formulation of conservation policy, see Prasad, A. 1994. Forests and subsistence in colonial India: a study of Central Provinces, 1830-1945. Ph.D. dissertation, Jawaharlal Nehru University, New Delhi; Rangarajan, M. 1996. *Fencing the forest: conservation and ecological change in India's Central Provinces, 1860-1914.* Oxford University Press, New Delhi; and Sivaramakrishnan, K. 1996. Forests, politics, and governance in Bengal, 1794-1994, Ph.D. dissertation, Yale University, New Haven. Also see Sivaramakrishnan, K. 1996. *op. cit.* for an analysis of the influence of institutional location in the shaping of colonial conservation policy.

[12] A literal understanding of the term desiccation, of course, is the drying up of something. I use the 'desiccationist' discourse through this paper to incorporate a larger body of ideas, centered on the connections between deforestation on the one hand, and increased erosion, flooding, and overall aridity on the other.

[13] My use of the word 'science' and 'scientific' refers to a generally accepted body of literature, one that is documented within scientific and professional journals, and reviewed and critiqued by disciplinary peers.

[14] Rajan, R. S.1994. *op. cit.*; Grove, R. 1995. *op. cit.*

[15]Other analyses of the desiccation discourse, such as those for Africa, have also failed to examine the nature of the American influence. Beinart refers briefly to the American Dust Bowl while describing the international context within which concerns over South African erosion were being voiced. Analyses of the question of whether or not the Saharan Desert is expanding southward have tended to be ecological rather than historical, although Tony Binns (Binns, T. 1990. *op. cit.*) demonstrates that the writings of E. P. Stebbing of the Indian Forest Service, during the 1930s, played a critical role in initiating the myth. Binns does not explore the larger context within which Stebbing was writing. In attempting to deconstruct what they refer to as the myth of environmental degradation in parts of West Africa, Fairhead and Leach (Fairhead, J. and M. Leach. 1995. False forest

history, complicit social analysis: rethinking some West African environmental narratives. *World Development* 23: 1023-1035.) also fail to note an American influence in generating an exaggerated global degradation-desiccation discourse during the early to mid-20th century.

[16] Paul Barton, hydrologist at the Yale School of Forestry and Environmental Studies, informs me that the notion of forests acting as sponges remains a commonly accepted model of forest functioning outside the forestry and ecological communities in the United States.

[17] Saberwal, V. K. 1997. *op. cit.*

[18] Schiff, A. 1962. *Fire and water: scientific heresy in the Forest Service.* Harvard University Press, Cambridge; Dodds, G. B. 1969. The stream-flow controversy: a conservation turning point. *The Journal of American History* 56: 57-69.

[19] Marsh, G. P. 1864. *Man and Nature: or physical geography as modified by human action.* C. Scribner, New York.

[20] Hough, F. B. 1878, 1889, 1882. Report upon forestry, Vol I-III, Washington.

[21] Williams, M. 1989. *The Americans and their forests: a historical geography.* Cambridge University Press, New York.

[22] Dana, S. T. 1956. *Forest and range policy: its development in the United States.* McGraw Hill Book Company, Inc. New York.

[23] Schiff, A. 1962. *op. cit.* p. 120.

[24] *Ibid*.

[25] *Ibid.* p. 119.

[26] *Ibid.* pp. 117-120.

[27] Quoted in Schiff, A. 1962. *op. cit.* p. 126.

[28] Chittendon, H. M. 1909. Forests and reservoirs in their relation to streamflow, with particular reference to navigable rivers. Reprinted from the *Transactions of the American Society of Civil Engineers.* Paper No. 1098, Vol. LXII: 245-545.

[29] Chittenden, H. M. 1909. *op. cit.*, pp. 266-267, in footnote.

[30] Moore, W. L. 1910. The influence of forests on climate and floods. Report prepared for the House of Representatives, Unites States, Committee on Agriculture. Government Printing Office, Washington.

[31] Brooks, C. E. P. 1927. The influence of forests on rainfall. *Empire Forestry Journal* 6: 210-218.

[32] U.S. Statutes at Large, XXXVI, pt. 1, p. 962, quoted in Dodds, G. B. 1969. *op. cit.* p. 65.

[33] Hyot, W. G. and H. C. Troxell. 1932. Forests and stream flow. Preprint of paper to be presented to the American Society of Civil Engineers.

[34] Lowdermilk, W. C. 1930. *op. cit.*, p. 21.

[35] Editorial, *American Forests*. 1937. V. 43, p. 173.

[36] See Lowdermilk, W. C. 1930. *op. cit.*

[37] Burr, E. 1911. The influence of forests on streamflow in the Merrimac River Basin. House Documents, 62nd Congress, Ist Session, Vol 8, p. 23, quoted in Lowdermilk, 1930, p. 27.

[38] Harts, W. M. 1909. The relation of forests to streamflow. Professional Memoirs, Engineering Bureau. U.S. Army Vol. I, No. 4. Quoted in Lowdermilk, 1930, p. 29.

[39]Lowdermilk, W. C. 1930. *op. cit.*

[40] see for example, Bates, C. G. 1924. The erosion problem: Erosion is the cause of many calamities. *Journal of Forestry* 22: 498-505.

[41] Chapman, H. H. 1933. Influence of overgrazing on erosion and watersheds. *Civil Engineering* 3: 74-78.
[42] Stevens, J. C. 1933. Fantastic notions of erosion. *Civil Engineering* 3: 286.
[43] J. F. Deeds, 1933. Climatic eccentricities initiate abnormal erosion. *Civil Engineering* 3: 287.
[44] Jones, B. E. 1933. Grazing control stops no floods. *Civil Engineering* 3: 333-334.
[45] Sears, P. B. 1935. *Deserts on the March*. University of Oklahoma Press, Norma.
[46] Lowdermilk, W. C. 1935. Civilization and Soil Erosion. *Journal of Forestry* 33: 554.
[47] *Ibid.*
[48] *Ibid.*
[49] Schiff, A. 1962. *op. cit.*
[50] W. G. Hyot (Geological Survey), July 15, 1937. Quoted in Schiff, A. 1962. *op. cit.* p. 147.
[51] Quoted in Schiff, A. 1962. *op. cit.* p. 158.
[52] See Bosch and Hewlett (1982) *op. cit.*
[53] See for example, Hamilton, L. 1987. *op. cit.*
[54] Schiffs, A. 1962. *op. cit.* p. 150.
[55] Saberwal, V. K. 1998. *op. cit.*
[56] Schmaltz, N. J. 1980. Forest researcher: Raphael Zon. *Journal of Forest History* 24: 25-39.
[57] Dodds, G. B. 1969. *op. cit.* p. 68.
[58] Jeremy Swift's comment (quoted in Forse, B. 1989. The myth of the marching desert. *New Scientist* 4: 3132), regarding 'big policies based on very little bits of science' made in the context of African rangeland development policies is applicable in this context. So too is Mace's comment: 'Sometimes we are so sure of something that we don't need to see the evidence. That Africa's rangelands are being reduced to desert through overgrazing by domestic livestock is received wisdom. But as has been mentioned in recent meetings such a view may be seriously flawed.' (Mace, R. 1991. Conservation biology: overgrazing overstated. *Nature* 349: 280-281).
[59] Rajan, R. S. 1994. *op. cit.*
[60] Baden-Powell, B. H. 1877. Note on the demarcation of the forest area in districts containing hill or mountain ranges. *Indian Forester (IF)* 2: 239-265.
[61] Moir's Report on the Chos of Hushyarpur (1883). Reprinted in 1884. *IF* 10: 271-277; Ribbentrop, B. 1887. Memorandum on the forests of the Nahan State, Punjab. *IF* 12: 85-87; Anon. 1891. The Chos of Hoshiarpur again! *IF* 17: 215-216; Anon. 1895. Note on the Patiala Western Siwaliks. *IF* 21: 366-370.
[62] Gleadow, F. 1903. Navigability of the Garonne. *IF* 29: 148-150.
[63] Cooper, R. T. 1887. Our empire of rivers. *IF* 13: 198-213.
[64] *Ibid.*, p 206.
[65] For a discussion of the link between the notion of a balance in nature, and developments in ecological thinking, see Worster, D. 1995. *Nature's economy: a history of ecological ideas.* Second edition. Cambridge University Press, New York.
[66] H. F. Blanford, 1881. The Indian monsoon rains. *IF* 6: 185-202.
[67] Blanford, H. F. 1885. Indian meteorological memoirs, Vol III, Part II, The rainfall of India. Excerpted in 1888. *IF* 14: 34-47.
[68] Anon. 1889. Forests and rainfall. *IF* 15: 39-41.
[69] Parquet, L. 1889. The influence of forests on water supply. *IF* 15: 317-320; Lyman, J. D. 1989. Forests, rainfall and climate. *IF* 15: 458-460.

[70] *Ibid.*, p. 459.
[71] Henri, M. E. 1903. Plains forests and underground waters: observations made in the forest of Mondon (Meurthe and Moselle). March and April numbers of *Revue des Eaux et Forêts*. Reprinted in 1904. *IF* 30: 60-65, 109-115.
[72] *Ibid.*, p. 114-115; Gleadow, F. 1898. Forests and Sub-soil Waters. *IF* 24: 420-422; Gleadow, F. 1902. The effect of Forests on the circulation of water at the surface of continents. *IF* 28: 1-9.
[73] Nisbet, J. 1908. Indian famines and Indian forests. *IF* 34: 649.
[74] Hill, M. 1916. Note on the enquiry by the Government of India into the relation between forests and atmospheric and soil moisture in India. *Forest Bulletin*, No.33, p. 41.
[75] *Ibid.*, p. 13. Emphasis added.
[76]*Ibid.*, p. 17. Emphasis added.
[77] *Ibid.*, p. 29.
[78] See Saberwal, V. K. 1998. *op. cit.* for a more detailed discussion of this extrapolation within the Punjab.
[79] Anon. 1911. *IF* 3&4: 119-130.
[80] Pearson, R. S. 1907. The level of subsoil waters with regard to forest. *IF* 33: 57-69.
[81] Anon. 1909. The enquiry into the influence of forests on the amount and the distribution of rainfall in India. *IF* 35: 268.
[82] Anon. 1917. Forests and rainfall. *IF* 43: 419-425.
[83] Mill, H. R. 1918. Forests and rainfall. *IF* 44: 31-35.
[84] Zon, R. 1921. The effect of forests upon streamflow. *IF* 47: 82-90.
[85] Anon. 1922. Forests in relation to streamflow and erosion. *IF* 48: 516. Reprinted from *Nature*, Vol. 109, No. 2735.
[86] Champion, H. G. 1928. Forest and streamflow experiment at Wagon Wheel Gap, Colorado. Final report, on completion of the second phase of the project. *IF* 54: 675.
[87] Benskin, E. 1930. Forest and stream flow. *IF* 56: 521.
[88] *Ibid.*, p. 523.
[89] Anon. 1927. Forest destruction and its effects. *IF* 53: 411-412.
[90] Lowdermilk, W. C. 1935. The role of vegetation in erosion control and water conservation. *IF* 61: 123-131. Reprinted from *Journal of Forestry*, May 1934.
[91] Glover, H. M. 1936. The Hoshiarpur Siwaliks from the air. *IF* 62: 330-333. Gorrie, R. M. 1937. Note on soil erosion in the Punjab. *IF* 63: 67-73; Gorrie, R. M. 1937. The causes of floods in the Punjab. *IF* 63: 119-122; Hamilton, A. P. F. 1937. Siwalik erosion. Superintendent Government Printing, Punjab, Lahore.
[92] Anon. 1933. Assessing forest losses. *IF* 59: 699-706; Gorrie, R. M. 1937. The measurement of soil erosion and run-off: an attempt and some results. *IF* 63: 839-846.
[93] Anon. 1933. Assessing forest losses. *IF* 59: 702
[94] Holland, L. B. and H. M. Glover. 1931. Erosion in the Punjab Himalaya and its probable effect on water supplies. *IF* 57: 8-20.
[95] *Ibid.*, p. 14.
[96] Baden-Powell, B. H. 1879. The Chos of Hoshiarpur. *IF* 5: 3-34.
[97] *Ibid.*
[98] Anon. 1931. Forests, climate, erosion and innundations. *IF* 57: 302-306.
[99] *Ibid.*, 304.
[100] Ryan, R. M. 1931. Improved control of alluvial rivers. *IF* 57: 533-534. Reprinted from *Indian Engineering*.

[101] Anon. 1931. Erosion in the Punjab Himalaya. *IF* 57: 530-532. Reprinted from *Indian Engineering*.
[102] Smythies, E. A. 1938. Soil Erosion Problems in India. *IF* 64: 707.
[103] Gorrie, R. M. 1936. Punjab Erosion Conference. *IF* 62: 473-476.
[104] *Ibid.*, p. 474.
[105] *Ibid.*, p. 476.
[106] Stebbings, E. P. 1938. The man-made desert in Africa - Erosion and drought. *IF* 64: 314-323, 383-393. Extracted from the Supplement to the *Journal of the Royal African Society* January 1939, V. 37.
[107] Smythies, E. A. 1938. Soil erosion problems in India. *IF* 64: 707.
[108] Smythies, E. A. 1938. Soil erosion problems in India. *IF 64:* 705.
[109] Gorrie, R. M. 1948. Countering desiccation in the Punjab. *The Geographical Review* XXXVIII: 30-40.
[110] Sitholey, B. S. 1949. Land erosion. *IF* 75: 354.
[111] Tiwari, K. M. 1984. Measures to control floods in the Ganges Basin. *Indian Forest Records* (New Series), 3(1). 14 pp. Forest Research Institute and Colleges, Dehra Dun, India.
[112] *Ibid.*, p. 2.
[113] Rajan, R. S. 1994. *op. cit.*
[114] Binns, T. 1990. *op. cit.*
[115] [127]I would empahsize, once again, that I am not suggesting a causality between developments in the U.S. and in India. Rather, my argument is that Indian foresters used writings of American foresters in a highly selective fashion, selective pressure being generated by the institutional context within which Indian foresters found themselves in.
[116] Rajan notes that opposition to forester and conservationist demands for more stringent conservancy measures was widespread throughout the British Empire, even as late as the 1950s. The alarmist discourse of the 1930s would have provided much needed ammunition to conservation agencies worldwide.
[117] See Wiens, J. 1977. On competition and variable environments. *American Scientist* 65: 590-597; Strong, D., R. Simberloff, L. G. Abele, and A. B. Thistle (eds) 1984. *Ecological communities: conceptual issues and the evidence.* Princeton University Press, Princeton, New Jersey; Botkin, D. 1991. *Discordant harmonies: a new ecology for the twenty-first century.* Oxford University Press, New York.
[118] Worster, D. 1995. *op. cit.*