Human Ecology in India
Some Historical Perspectives

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Before the spread of extensive settled cultivation, the Indian subcontinent would have been inhabited by territorial hunter-gatherers and shifting cultivators with cultural traditions of prudent resource use. The disruption of closed material cycles by export of agricultural produce to centres of non-agricultural population would have weakened these traditions. Indeed, the fire-based sacrificial ritual and extensive agricultural settlements might have catalysed the destruction of forests and wildlife and the suppression of tribal peoples during the agricultural colonization of the Gangetic plains. Buddhism, Jainism and later the Hindu sects may have been responses to the need for a reassertion of ecological prudence once the more fertile lands were brought under cultivation. British rule radically changed the focus of the country’s resource use pattern from production of a variety of biological resources for local consumption to the production of a few commodities largely for export. The resulting ecological squeeze was accompanied by disastrous famines and epidemics between the 1860s and the 1920s. The counteffows to tracts of intensive agriculture have reduced such disasters since independence. However, these are quite inadequate to balance the state-subsidized outflows of resources from rural hinterlands. These imbalances have triggered serious environmental degradation and tremendous overcrowding of the niche of agricultural labour and marginal cultivator all over the country.

Indian society is a mosaic of fishermen and shifting cultivators, toddy tappers and tea estate owners, nomadic shepherds and coal miners, village blacksmiths and computer programmers. Its people dwell in tribal huts in the heart of the rain forests of the Andamans, in fishing hamlets on the Kerala coast, in camps of itinerant well diggers on the Deccan plateau and in villages on the Gangetic plains. They live in the slums of Calcutta and the skyscrapers of Bombay, in the beach resorts of Goa and pilgrimage centres of the high Himalayas. The diversity of ecological niches that India’s huge population of 750 million collectively occupies is mind-boggling, as is the variety of belief systems, practices and regulations that governs the utilization of its natural resource base. Many of its towns still harbour wild populations of monkeys thanks to the religious protection they enjoy, although the vast herds of blackbuck that once roamed its countryside are all but gone. While farmers fight bitterly over boundaries of fields in the irrigated tracts of Rajasthan, tribal peoples of the northeast still practice shifting cultivation on communally owned land. While village grazing lands are encroached upon for cultivation, state forests are dedicated to the production of eucalyptus for industry. Such complexity obviously renders generalizations difficult. Nevertheless, we venture to present here an interpretation of how this mosaic of human communities may have been put together over historical times.

Geological background

The Indian subcontinent has had a remarkable geological history. When mammals made their appearance on earth 180 million years ago it had recently broken off from the great southern landmass that included South America, Antarctica and Africa. It was crossing the equator when the age of dinosaurs came to an end 65 million years ago. Fifty-four million years ago its northern tip bumped into the Asian plate; in another four million years it had established contact along the remaining boundary. The aftermath of this collision was the Himalayas, rising at a rate of 2 cm a century to produce the tallest mountains in the world. This barrier has thus been continually rising over the last 50 million years so that most mammals have come to India through passes to the west, and to a lesser extent to the east of the Himalayas. Hominid fossils first appeared on the subcontinent in the Himalayan foothills 13 million years ago, continuing till 7 million years ago as a part of mammalian communities of wooded habitats. Then they disappeared, presumably victims of habitat changes brought about by the continuing uplift of the Himalayas.

Much later, members of our genus Homo moved on to the subcontinent, probably from their place of origin on the savannas of East and South Africa. Tool-using hominids arose in Africa some two million years ago; by one million years ago they had reached...
Java. Almost certainly then they would have colonised India at this time, but firm evidence of human occupation of India appears in the form of artefacts, such as hand axes, somewhat later, dated sometime between 700,000 to 400,000 years B.P. By this time, the uplift of the Himalayas was completed and a seasonal monsoonal climate had become established. The hunter-gatherer populations of our own species, Homo sapiens, came to cover much of the country thinly during the remaining part of the Late Pleistocene, when the climate fluctuated between periods of weak, moderate and strong monsoon. The wetter hills of the Western Ghats, the west coast and the northeastern hill regions as well as the Gangetic plains, however, remained unoccupied until the Terminal Pleistocene, 20,000 years B.P., when the monsoons became distinctly weak at the height of glaciation in the northern latitudes (see Table 1).

**Prudent predators**

We can only speculate on the ecological niche relationships of these hunter-gatherer populations. In the productive, stable tropical environments that they inhabited, most would have been organized in bands with strong bonds to their territories, often in conflict over land and water use with neighbouring groups. Each endogamous tribe would have adapted itself culturally to its biological and physical environment, having learnt by trial and error what to eat and what to avoid, how to look for food and how to keep away from predators. Each such tribe may then be thought of as occupying a distinctive, spatially disjunct niche. There would be relatively little variation amongst members of a group in the niche occupied, although women may have been more concerned with gathering tubers and men with hunting mammals, and some individuals may have specialized in fashioning stone tools and others in building up a store of knowledge on the progress of seasons and what animals are best hunted in which season.

**Material cycles**

In such a society the cycles of materials, organic and inorganic, would be largely limited to the territory of any tribe. There may of course be some flows across the territorial boundaries due to natural movements of air, water and living organisms. There would also be some intertribal exchange of materials such as salt or flint tools and shells and feathers. However, such flows across territorial boundaries would tend to be insignificant compared to the flows induced by the consumption of food, fuel and other resources within the limits of a territory (see Figure 1).

These largely closed local cycles of materials would promote a vested interest on the part of the territorial group in sustaining the resource base. This is because human beings are slow-breeding species, unable to convert quickly an abundance of resources into supporting a larger population size. On the other hand, even occasional severe resource shortages in the territory can greatly weaken the territory holders and expose them to aggression and possible expulsion or annihilation at the hands of hostile neighbours. Hunter-gatherers in stable, productive environments with relatively fixed territories would therefore be expected to develop cultural traditions of sustainable utilization of their resource base.

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### Table 1. Climatic history of the Indian subcontinent

<table>
<thead>
<tr>
<th>Geological period</th>
<th>Years BP</th>
<th>Climate</th>
<th>Geomorphic data</th>
<th>Human population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Holocene</td>
<td>&lt;4000</td>
<td>Moderate monsoons</td>
<td>Saline lakes in western India</td>
<td>Agricultural settlements cover the subcontinent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Beginning of agriculture</td>
</tr>
<tr>
<td>Early Holocene</td>
<td>10,000–4000</td>
<td>Strong monsoons</td>
<td>Freshwater lakes entrenched streams</td>
<td>denser populations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>stable dunes</td>
<td></td>
</tr>
<tr>
<td>Terminal Pleistocene</td>
<td>20,000–10,000</td>
<td>Distinctly weak monsoons</td>
<td>Hypersaline lakes choked rivers active</td>
<td>Human population spread throughout the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dunes</td>
<td>subcontinent at low densities</td>
</tr>
<tr>
<td>Late Pleistocene</td>
<td>70,000–20,000</td>
<td>Weak to moderate</td>
<td>Entrenched streams</td>
<td>Hunter–gatherers in small groups, wetter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>monsoons</td>
<td>stable dunes</td>
<td>tracts not colonized</td>
</tr>
<tr>
<td>Early Late Pleistocene</td>
<td>125,000–70,000</td>
<td>Strong monsoons</td>
<td>Reddish soils (dating doubtful)</td>
<td>Hunter–gatherers in small groups nomadic</td>
</tr>
<tr>
<td>Middle Pleistocene</td>
<td>700,000–125,000</td>
<td>Monsoonal seasonal</td>
<td>No data</td>
<td>First evidence of human</td>
</tr>
<tr>
<td></td>
<td></td>
<td>climate</td>
<td></td>
<td>occupation</td>
</tr>
<tr>
<td>Lower Pleistocene</td>
<td>2 million – 0.7 million</td>
<td>Relatively dry</td>
<td>Volcanic ashes streams-aggrading</td>
<td>Hominids found in both Africa and Java but no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>seasonal climate</td>
<td></td>
<td>definite evidence of human occupation in India</td>
</tr>
<tr>
<td>Pliocene</td>
<td>8 million – 2.0 million</td>
<td>Tropical equatorial</td>
<td>Volcanic ashes</td>
<td>No data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to strongly monsoonal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miocene</td>
<td>25 million – 8 million</td>
<td>Tropical equatorial</td>
<td>No data</td>
<td></td>
</tr>
</tbody>
</table>

Source: S N Rajaguru Deccan College Pune, personal communication; R K Pant Physical Research Laboratory Ahmedabad personal communication

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The commumality of interests in the health of the resource base of their territory would characterize the organization of such hunter–gatherer societies, which Dasmann has termed ecosystem people.  

### Social relationships

The social relationships amongst members of such a tribe would be governed by kinship and mutual help. Their belief systems extend these relationships from the social to the natural environment, treating rivers as mother goddesses, totemic animals as brethren, prey species as mutualists. Many elements of natural environment are offered protection from harm at human hands, as well as gifts of valuables, including human sacrifices, to ensure bountiful returns. The resultant protection of elements of environment, be they ponds or groves or all members of a species such as the peepal tree (*Ficus religiosa*) or specific individual trees or animals, can in fact serve to promote long-term persistence of biological resources. While couched in terms of religion, such practices might then have helped territorial hunter–gatherers to safeguard the health of their resource base. Many such practices have continued on the Indian subcontinent to the present day and have helped protect a wide diversity of biological resources.

There would, of course, be no guarantee that such practices would lead to the long-term preservation of...
all elements of the biological environment. However, so long as the total demand on the resources remains limited, the human populations would tend to reach equilibrium with their resource base after the elimination of such elements as were overutilized. Limitation of demand on resources used for subsistence would then be significant to ensuring sustainable resource use. Even at the hunting-gathering stage, the demand on some resources used as commodities, for instance ivory, could increase without limit and lead to over-utilization. Drastic environmental changes could also result in a disturbance of such equilibrium as human populations might have reached. Climatic changes attendant on the withdrawal of Pleistocene glaciation 10,000 years ago seem to have resulted in the extinction of many species all over the world; this could in part be due to the overextension of human hunting after major changes had taken place in the prey populations. The baboon and hippopotamus became extinct in India at this time; perhaps because of overhunting.  

**Neolithic revolution**

The creeping back of the forest cover associated with this climatic change was probably responsible for a food crisis prompting hunter-gatherer societies to domesticate animals and cultivate plants. The crisis was not equally acute everywhere; it was perhaps most serious in the Middle East, where domestication of animals, and cultivation of plants began to gather momentum some 10,000 years ago. Wheat, barley and lentils amongst plants and cattle, sheep and goats amongst animals were first domesticated there, and this change undoubtedly also provided the stimulus for the beginning of agriculture and animal husbandry on the Indian subcontinent. The earliest evidence comes from Mehrgarh in Baluchistan in present-day Pakistan around 8000 years BP. There is a disputed claim for the origin of rice cultivation in the Gangetic valley as early as 7000 years BP; but it is more likely that rice was domesticated in India some three thousand years later or diffused from outside. It is, however, definite that a number of pulses – horse gram, hyacinth bean, green gram and black gram – were indigenous brought under cultivation in India around 4000 years ago. The humped cattle, the zebu, is also likely to have been independently domesticated on the Indian subcontinent. It is these cattle and the pulses that give Indian agriculture and animal husbandry its special character.

**Husbandry and ecology**

Husbanding of plants and animals radically transforms the ecological niche of human societies. Hunter-gatherers depend on a tremendous variety of plant and animal foods, ranging from insects and fish to mammals as large as elephants, and from tubers and grass seeds to the pith of palm trees and fleshy fruits. Agricultural–pastoral people tend a much smaller number of plant and animal species, although in rain forest environments these may still run into a hundred or more. However, the level of production per unit area from these species is far greater. Such harvests imply an intensification of the outflow of materials from small areas of cultivated or intensively grazed lands. This is compensated for by inflows onto these lands over years of fallow, or by addition of animal dung or plant matter brought from surrounding lands. Hunting–gathering does not generate easily stored surplus harvests; husbanding does so. Cereal grain or meat on the hoof produced in one region can then be removed to distant localities. This encourages material flows over spatially much larger scales, disrupting the smaller closed cycles of erstwhile tribal territories (see Figure 2).

**Social organization**

This transformation of the material flows in turn affects social organization. An intensively cultivated plot of land or an intensively tended herd of animals is more effectively looked after by a small group of
people, the family unit. At the same time, the motivation for guarding and maintaining the health of the resource base of a larger territory in which hunting and gathering of wild foods and gathering of organic manure or firewood continues becomes weaker. An area smaller than the earlier tribal territory from which a local community gathers resources may still be managed communally, but with less serious attention. On the other hand, the generation of surplus by agriculture and animal husbandry opens up altogether new dimensions of the human niche. In this situation, some individuals can subsist entirely by usurping the surplus of others. While doing so, they may serve a positive function such as organizing exchange over ecologically diverse regions, or providing information on the march of seasons. On the other hand, they may simply usurp the surplus by force or guile. Such usurpation is best achieved by groups of individuals banding together for the purpose—priests and warriors, the ruling elite of a chieftain, and in a later stage bureaucrats associated with the state. This elite would attempt to establish its territorial control, more or less direct, over regions often larger than erstwhile tribal territories. Generation of the surplus would also promote material exchanges over larger spatial scales. With this, the barriers to cultural and genetic exchange prevalent amongst tribes at the hunter-gatherer stage would be weakened.

The agricultural–pastoral people would have an edge over hunter-gatherers whenever they come into conflict over land. The population densities of the former would be greater, and their surpluses would enable them to keep fighting for a longer period. They may also learn to use the power of domesticated animals like horses against their foes. The technology of agriculture and pastoralism would then tend to spread into regions suitable for this mode of resource use. Hunter-gatherers would tend to be eliminated from ecological niches suitable to agricultural–pastoral people. The belief systems of the agricultural–pastoral people would be geared to help in this process, depicting the hunter-gatherers as lowly, alien, dangerous, and they as well as their resource base of wild animals and vegetation as something that ought to be destroyed or suppressed. In the phase of expansion, agricultural–pastoral people would have little need for sustainable resource use, and their belief systems would eschew the hunter-gatherer traditions of nature worship and protection of natural resources (see Figure 3).

Agricultural–pastoral people spread over the Indian subcontinent in many phases. Without metal tools, they could not readily penetrate the moister forests such as those of the Gangetic plains or the west coast. The habitat most favourable to them for cultivation was along the smaller water courses in the

Figure 3. Flows of material and people accompanying agricultural colonization. When settled agricultural populations are newly colonizing river valley plains they would tend to use the cultivable lands exhaustively without making good the losses induced by outflows of materials. As cultivated lands lose fertility, people would move on to settle new areas. Settlements adjacent to cultivated land represent villages, the larger habitation in the centre, towns. The thickness of an arrow indicates the intensity of the flow.
drier tracts of northwestern India, the Indus plains and the Deccan peninsula. This is where agricultural settlements developed over the period 6000 to 1000 BC. There was also animal husbandry, including nomadic cattle herding, and this has left traces such as the ash mounds of the Deccan. It has been suggested that there was gradual deforestation in parts of the Deccan over this period, with timber fences slowly giving way to stone walls around the camps of the pastoralists. In the moister tracts over the rest of the country, there would have been some slash-and-burn cultivation, but this has left no trace. Hunting-gathering, along with slash-and-burn, might have continued to dominate all the moister tracts of the country.

**River valley civilizations**

The first urban civilization of the Indian subcontinent embraced a very wide region of the northwest. Archaeological evidence suggests that this culture was familiar with the use of the plough. They had also begun to add indigenous rainy-season crops like rice and pulses to the winter crops of wheat, barley and lentils of west Asian origin. The agricultural surpluses thus produced permitted the establishment of many towns, where the surplus served to promote further processing and exchange of materials, as well as artisanal and trade activities. Exchange over distances, as opposed to barter on a small scale, called for maintenance of records, and the Indus Valley civilization offers the first evidence of literacy in Indian history. The gradual weakening and disappearance of the urban centres of this civilization has been attributed to a variety of possible causes. The best-documented evidence relates to shifting of the river courses due to geological changes associated with the continuing uplift of the Himalayas. Satellite imagery shows clearly the palaeochannels of the river Saraswati which dried up when the Sutlej shifted its course westward to join the Indus and the Yamuna shifted eastward to join the Ganges (Figure 4). There have also been suggestions of climatic change as evident from palaeobotany, the flooding of the Indus and salination of agricultural soils due to irrigation.

**Land use and religion**

Iron had been introduced to India by about 1000 BC, and is associated with the Painted Grey Ware pottery culture of the northwest, the Black and Red Ware pottery culture of central India and the megalithic cultures covering much of the peninsula. Iron, along with fire, made it possible to bring the middle Gangetic plains under intensive agricultural-pastoral colonization, with wet-paddy cultivation as a key element. Yajnas, the large-scale sacrificial rituals involving the burning of vast quantities of wood and animal fat, catalysed this process: Brahman priests moved into forests to establish outposts and begin the clearing of forests. The indigenous people who opposed yajnas were depicted as demons, from whom the Kshatriyas, or warrior caste, protected the Brahmins. The burning of the entire Khandava forest (in the vicinity of present-day New Delhi) with all the living creatures contained therein and the massacre of animals by the army of the king Dushyanta as described in the epic *Mahabharata* bear witness to this process. The colonization of the fertile plains of the Ganges took place in the first millennium BC.

The archaeological evidence that becomes available from this period onwards allows more definite statements about human population changes and how these relate to the ecological setting. The land-to-man ratio would be high in the phase of expansion; for instance, LAt suggests a density of 0.75 people per km² for Kanpur district in the Ganges-Yamuna divide for the Black and Red Ware period around 1350 BC; this would be accompanied by a high ratio of livestock-to-man. There would also be more forest to be burnt and colonized as older lands were over-used and exhausted (Figure 3). An ethic of exhaustive use of resource base with the yajna as its cornerstone would then be the expected belief system. If the human population quadrupled over the next eight centuries of agricultural growth, as has been argued, then much of the most fertile land would have come under the plough, and the livestock-to-man ratios and the amount of forest land available for further colonization would have begun to plummet. The society would then need a new belief system; stressing more careful, more sustainable resource use. Such a belief system would appeal to the agricultural-pastoral component of the population, while Brahmins, beneficiaries of the yajna system, would be expected to oppose it. Buddhism and Jainism, often described as heterodox – that is, in opposition to the Brahmanic religion – appear to have been responses to this need, with their protests against the hegemony of Brahmins and the wasteful burning of endless quantities of clarified butter and of wood and the slaughter of animals at the sacrificial rituals.

**Surplus and social change**

With large tracts of fertile lands in the middle Gangetic plains under wet-paddy cultivation, the total quantity of surpluses generated and available for usurpation would be substantial. This surplus would create a large niche for those engaged in resource processing, artisans and craftsmen; for those involved in exchange, the traders; for those generating the knowledge base required for processing, exchange and usurpation, the learned classes; and for the managers of usurpation, the priest-warrior combine. All these would come together in urban centres which would flourish by organizing large flows of materials from fields and pastures, as well as rivers, seas and mines, into these cities. The larger the surpluses, the greater the possibilities of integration of material flows over larger spatial scales, with chieftains coming under the sway of kingdoms and empires.
The Mauryan empire which flourished on the Indian subcontinent from the fourth to second centuries before the Christian era was based on these large surpluses. This institution naturally had an interest in further enhancing the surpluses; hence the occasional resort to an irrigation system, and the use of prisoners-of-war as agricultural labour. The state endeavoured to enhance its revenue by clearing forest to extend agriculture; this was kept under careful control, the cutting down of forests without permission from the state was prohibited. Forests, rivers and hills as natural topographical features formed boundaries between the kingdoms in the absence of linear boundaries demarcated on maps. Forests as frontier zones were therefore deliberately maintained in order to provide the required flexibility of boundaries between the states.

As the Arthashastra, the famous manual on statecraft, mentions, such boundary forests also served as a source of supply of elephants for the armies and the state engineering corps, and a person found to have killed an elephant suffered the death penalty. In fact, the elephant became a vital resource for which Indian states as well as those in western Asia had an insatiable appetite. It became a prime commodity for which demand could grow without limit and which
was therefore liable to overharvest and exhaustion. Indeed, the next two millennia witnessed the elimination of elephant populations from one region after another over the Indian subcontinent, in spite of the imposition of taboos on hunting of elephants for meat and on capture by private individuals.31

Resources and commodities

The trade that flourished in this period would also have led to an escalation of demand for many other resources that would become commodities. These included animal furs and musk, sandalwood, and timber for shipbuilding. It is likely that some of these were also subjected to gradual overuse and exhaustion, though we have no firm evidence of such a process. However, we have the evidence of Ashoka’s edicts in the third century BC and the Jain tradition of the eschewal of all violence which was slowly building up, suggesting that there was developing a need for a belief system oriented towards a more and more sustainable resource use. This probably reflected nearly complete saturation of cultivated land at the available level of agricultural technology accompanied by a growth in human population. Such growth in human population is suggested by the increase in the number and size of settlements revealed by archaeological data from the mid-first millennium BC. However, it has been argued that evidence from the first millennium AD suggests a decline in urban sites in the Ganges plain, with a possible migration of population into rural areas, thus increasing the pressure on rural resources.32,33 The decline of towns may have been due to devastating floods in some areas, which may have affected soil fertility. In the Ganges plain the inscriptive evidence of large numbers of grants of land dating to the end of the first millennium AD and later emphasizes the importance of maintaining village boundaries and suggests a decrease in land readily available for cultivation.34

Caste society

A fall in expropriable surplus would lead to a shrinkage in the spatial scale over which material flows can be organized, with a reduction in urban concentrations and a breakdown of empires into smaller kingdoms or the continuation of chiefdoms. Such a process seems to have been set in motion in the Indo-Gangetic plains after the fifth century of the Christian era; it is reasonable to assume that this was an era of resource shortages when the need for sustainable use of resources became increasingly evident. Indian society seems to have responded to this crisis through an elaboration of the caste system. The caste system divided the society into innumerable endogamous groups within which most marriages and much social intercourse are restricted. The endogamous groups of caste society traditionally resembled tribal groups, from which they might in large part have been derived, in having a restricted geographical distribution, and in being self-governing as far as intragroup transactions were concerned. Each endogamous group tended to follow the customary pursuits of the group, a hereditary, rather well-defined mode of subsistence. In tribal societies, the different endogamous groups tend to have non-overlapping distributions, whereas in a caste society several endogamous groups live together.35

Competition and reciprocity

The modes of subsistence of such co-occurring groups tend to be diversified in ways that serve to minimize the competition between them. Thus in the hilly Sirsi taluka county of Utara Kannada district of Karnataka state, nine different endogamous groups of people use plant material to fabricate a variety of implements or structures. This resource use is highly diversified: for instance, only Christians employ cane to produce furniture, and only Chamagars use Phoenix palm to produce mats and brooms. While both Badigars and Acharis use Careya arborea, they fabricate different articles (Figure 5). In the same district, the coastal taluka of Kumta has three endogamous groups of fishermen; one of these fish in the rivers, the second in the estuaries, and the third in the seas. One may thus characterize the endogamous groups of the Indian caste society as occupying rather narrow niches with relatively little niche overlap with other sympatric groups.36

These endogamous groups lived together in multicaste village communities knit together in a web of reciprocity. It was, of course, an egalitarian system with lower-status castes providing services far in excess of returns from the higher-status castes. Nevertheless, this system moderated the intercaste competition and permitted the multicaste village community to act in a relatively cooperative fashion. Perhaps in response to the resource crunch, these village communities developed many traditions that were compatible with sustainable resource use. Some of these were elements of nature worship such as sacred groves or sacred trees which may have persisted from hunting-gathering times; others might have been newly elaborated. Thus in western Maharashtra the harvest and supply of fuelwood from the village forest to all village households was the responsibility of members of a particular endogamous group, the Mahars. The Mahars were also responsible for guarding the entire village territory. They would receive a fraction of agricultural produce and other services in return for these services. Since each village would have just one or a few closely related Mahar families who would expect to live in that village, following that mode of subsistence generation after generation, they would be expected to be motivated to carry out harvests from the village forest in a sustainable fashion.37

The sedentary component of the human community was complemented by a nomadic component. These
nomadic groups provided occasionally needed services such as well-digging or fortune-telling. They also carried on trade in salt, trinkets and other consumer goods. The nomads tapped the forest, grazing land and wild animal resources of tracts away from settled villages. Again their modes of subsistence were so diversified that they tended to have a monopoly over certain resources of certain regions, and had developed traditions of their sustainable use. Thus in western Maharashtra hunting of blackbuck was the exclusive privilege of Phasepardhis, who traditionally released any fawn or pregnant doe caught in their snares.8 (Figure 6).

Disequilibrium and new technology

It is plausible that this organization conferred on the caste society a greater potential for sustainable resource use and perhaps led to an equilibrium in some habitats and with respect to some specific resources. However, population pressure probably continued to mount throughout this period, although the rate of population growth might have been rather low. The introduction of new methods of irrigation is likely to have been a response to the resulting disequilibrium. The Persian wheel, probably introduced in the seventh century AD, improved well irrigation in many parts of northern India and is believed to have made a substantial difference to agricultural production as well as allowing castes with access to such technology to exert control over castes who lacked it.90 An equally interesting example from the Kaveri valley in Tamil Nadu points to the locally controlled tank irrigation being superseded by canals and systems of water control such as anicuts on the rivers built by the Chola rulers in the late first and early second millennia AD.90 The introduction of such new means of irrigation does suggest a disequilibrium in the control of resources.

These technological developments in irrigation, and many others such as those in metalworking, must have been profoundly limited by the fragmentation of knowledge encouraged by the caste organization of society. Formally organized knowledge was a monopoly of Brahmans, whose interest in the calendar and astrology meant steady progress in relevant disciplines such as mathematics. However, the Brahmans would have no dealing with activities such as
metal casting, so that knowledge of metallurgy would remain isolated and restricted to a few artisan castes. Similarly, indigenous medicine men such as the Vaidus of Maharashtra who dealt with naturally occurring herbs would not have access to formalized medical knowledge contained in the Sanskrit texts of Ayurveda, while the Brahmins who studied such texts would not be in touch with natural plant life. This undoubtedly played a role in the failure of the scientific method to develop in India as it did in Europe.

**Mughal Empire**

The arrival of the Mughals on the scene in the early sixteenth century did not make a great difference to the way in which Indian society functioned, although their mastery of horses and gunpowder enabled them to mop up surpluses over larger spatial scales and thereby build up an empire. It was by now a society which tended to emphasize closed cycles of materials from the non-cultivated lands of the village. These promoted social cohesion and persistence of traditions of sustainable resource use. There were flows of materials out of the cultivated lands, in the form of surplus grain collected as tax by the state, a system familiar from earlier times. However, the state taxed animal holdings very lightly, and forests and fisheries not at all. In fact, the early seventeenth-century Mughal Emperor Shahjahan had to remove a governor of Kashmir because he attempted to tax sheep flocks and fishing, which was against the prevalent custom. Similarly, a ruler of Jodhpur of the same era had to give up an attempt to harvest Prosopis cinerarea trees from the village of Khejadir when the local Bishnoi villagers chose to die rather than permit the cutting of trees sacred to them. The state did claim some rights over forests maintained as hunting preserves of princes, a tradition dating back at least to Mauryan times. In fact, the Mughal princes maintained very extensive tracts in this fashion. However, apart from claiming exclusive rights over hunting game, the state interfered little in the gathering of other forest produce from these lands by neighbouring villagers.

On the significant question of demography and ecology from the Mughal period onwards, it is possible to compute with a greater degree of accuracy than before the possible population size by drawing on the revenue records maintained by the Mughal state. Population estimates for the subcontinent at the beginning of the seventeenth century vary between 110 to 145 million, which allows some conclusions to be drawn about the impact on natural resources. But it must also be kept in mind that the population was not evenly distributed throughout the area held by the Mughals and there were pockets of over-utilization of resources as well as areas of under-utilization.
European expansion

In the eighteenth century, the Indian subcontinent, its people and its ecology were profoundly affected by European colonialism. It is therefore useful to look at the ecological context of the emergence of colonialism in terms of exploitation of human and natural resources before we turn back to the Indian subcontinent. While Indian society had remained largely in equilibrium with its resource base over the first millennium and half of the Christian era, European society had evolved along very different lines. It has been argued that in this latter situation the boundaries between endogamous groups were blurred, and an individual could occupy a niche rather different from his kin. Ecological niches of social groups were thus much broader and there were substantial overlaps. This meant that formal learning and artisanal activities could go together, a situation that must have played a positive role in helping European societies discover the scientific method basic to the growth of knowledge. The belief system of European society, Christianity, also stressed intensification rather than conservative use of the resource base. This is not to exclude the importance of other factors, but to focus on the ecological.

The consequence was a resource crunch which reached serious proportions when compounded by the climatic episode of a Little Ice Age beginning in the fourteenth century. The response of European society included the discovery of the scientific method, along with major innovations in processing of resources, greatly increasing access to energy trapped in fossil fuels like coal. The result was tremendously enhanced abilities to process, transport and usurp resources, opening up entirely new dimensions for the human ecological niche, just as food production had done at the end of Pleistocene glaciation.

Equipped with these abilities and spurred by the resource shortages haunting their native Europe, the Europeans began to fan out to other lands, occupied by hunter-gatherers, farmers, pastoral peoples, craftsmen and traders without access to the energy of fossil fuels and with learned classes without access to the scientific methodology of systematically growing knowledge. They usurped the niches of the hunter-gatherers and primitive agriculturists in all areas of moderate rainfall and moderate temperature, leaving to them only the high-rainfall zones such as Amazonia and the Andamans, cold coniferous forests like Siberia and deserts like the Kalahari. They could not totally usurp the niches of advanced agricultural societies, but shrank the niche space that they occupied, opening up many niches for the European people. The Indian subcontinent, too, came under their sway, and the effects on its ecology and people were profound. This expansion of European societies was accompanied by a belief system that regarded other societies as uncivilized and primitive, just as agricultural-pastoral people colonizing the Gangetic plains had viewed the indigenous peoples as demons.

Further, the expanding society venerated the marketplace and developed a culture of unlimited consumption of all sorts of materials that now became commodities.

Colonial rule

With their superior coercive powers and more efficient methods of transport and communication, the British were able to bring under a single rule an area vastly greater than even that encompassed by the Mauryan and Mughal empires in their heydays. This led to a suppression of armed conflicts on a very large scale, and opened up the possibilities of exchanging resources in times of need over large areas. Estimates of population size in the early nineteenth century range from 125 to 210 million; the census of 1872 shows a more definite figure of 255 million. This would indicate a favourable effect on the growth of the Indian population.

Such growth, however, could not be sustained for long, and the vigorous population growth suffered a setback in the late nineteenth and early twentieth century. The resource usurpers of pre-British India largely confined themselves to tapping the surplus of grain production from cultivated land. They made little attempt to usurp surpluses from non-cultivated land, except special items such as gems, precious stones and gold, elephants and spices. The British, on the other hand, greatly enhanced the material flows out of rural hinterlands through a number of devices. They stepped up the effective levels of taxation on agricultural production, increasing the proportion of grain removed. They promoted the production of cash crops such as cotton, jute and indigo, a much greater fraction of whose biomass went out of the village ecosystem altogether. Most significantly, they took control of vast tracts of non-cultivated lands and dedicated them to the export of teak, deodar (Cedrus deodara) and other timber or of tea and coffee (see Table 2). Thus, lands that were producing a great diversity of cultivated or natural plant produce for local consumption, came to produce just a few products: cotton, jute, indigo, teak, deodar, tea or coffee, all for export out of the locality, and often out of the country as well. Ironically, some of this export was dedicated to catalysing export trade; thus in the beginning teak was critical to British shipbuilding and deodar and much other timber served as railway sleepers and as fuel for the railway engines. This disrupted the largely closed cycles of energy and materials characterizing the territories under the control of villages of India, breaking down the cohesion of the village society, and destroying the traditions of sustainable use of the resources of the non-cultivated lands.

In India as elsewhere, the British usurped the ecological niches of the tribes by displacing them in order to set up tea and coffee estates in Assam and the Western Ghats, by banning their shifting cultivation over most of the Western Ghats and Central
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<td>1757–1857</td>
<td>Great Britain consolidates its rule over India. Totally unregulated exploitation of forests, with teak being in particularly high demand, especially for shipbuilding. Exhaustion of natural teak in all accessible localities including farmlands and village common lands.</td>
<td>1960–1980</td>
<td>With the exhaustion of the potential for selective felling from natural stands, clearing and raising of monocultural plantations of fast-growing species such as Eucalyptus gilbertensis. The forest-based industry also moves to tap more and more remote hilly areas, especially in the northeast. Degradation of common lands and encroachment upon them continues apace. As the rural population faces unprecedented difficulties in meeting their biomass needs, developing forest resources for rural people is taken up for the first time with the beginning of social forestry programmes. Forest-based industry takes advantage of these programmes to promote production of industrial wood on farmlands.</td>
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<td>1857–1938</td>
<td>Demand for wood, especially for railway sleepers, further escalates with rapid expansion of railway network. Demarcation of state-owned reserve forest for supplying urban-industrial needs. While these are supposed to be managed for sustainable yield, the necessary scientific data base is totally inadequate and in effect they are managed for gradual exhaustion of natural growth and its conversion to teak and coniferous forests. Village needs expected to be met from protected forests which become open-access resources subject to exhaustive use as community-based management systems break down.</td>
<td>1980–1990</td>
<td>Diversion of lands under control of forest department for other purposes slows down with the passage of stringent laws. There is mounting pressure to open up for selective felling the remaining untapped forests like those in Andaman and Nicobar Islands. Forest plantations of species like Eucalyptus fail to produce expected yields of timber because of problems like fungal diseases. Production of industrial wood on farmlands continues to gather pace. Common lands continue to deteriorate and programmes such as social forestry and wasteland development totally fail to involve or help poorer segments of village society. There is mounting conflict over the diversion of village common lands for the production of industrial raw material. Large-scale imports of timber and paper pulp from outside the country begin and adversely affect wood production on farmlands.</td>
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<td>1939–1945</td>
<td>All restraints on forest exploitation set aside in order to meet the war demands with extractions exceeding the prescriptions of Forest Working Plans several times. More remote forest areas earlier untapped also opened up for exploitation. Difficulties of transport during the war prompt British Government to encourage development of industries such as plywood within the country.</td>
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<td>1945–1960</td>
<td>Following war and independence forest-based industries develop very rapidly, substantially exceeding the limits of sustainable supply. Raw material is supplied to industry at highly subsidized rates by excessive selective fellings from natural stands. There is a spurt of release of forest lands for cultivation and relaxation of restriction on grazing within the forests to win votes. However, the attempts to revive village-based democracy and management of local resources fail. Village common lands continue to be degraded and encroached upon for cultivation.</td>
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India and by destroying their prey through overhunting, they substantially diminished the niche space occupied by the food producers by denying them access to non-cultivated lands. The resource processors and transporters of European civilization had by the nineteenth century tremendously greater access to resources because of their technological abilities to tap additional sources of energy and materials. They outcompeted and usurped the niche space of the handicraft workers and artisans, as well as the itinerant traders of India.  

This tremendous shrinkage of the niche space available to the Indian population was only marginally compensated for by new niches opening up as collaborators with the British in usurpation and exchange of resources, the clerks and trading partners. The literate castes of pre-British India, those involved in priesthood and administration, filled the clerical jobs; the traders and shopkeepers the role of trading partners. These groups indeed prospered as time went by, later moving into modern resource processing and industry. But the others, hunter-gatherers, artisans, nomadic pastoralists and itinerant traders, had all to squeeze into the already diminishing niche space for food production and suffered great impoverishment.

This process may be illustrated by the village of Kusnur in the Dharwad district of Karnataka, investigated recently by Srilanjith Bhattacharya. Figure 7 depicts the population of 29 endogamous caste groups of this village arranged in descending order. For a representative sample of these groups, both the traditional caste occupations and current occupations are given. It is evident that occupations involving processing of materials (for example, weaving and oil pressing) or transport (such as ferrying) have become unviable, and no new opportunities have opened up. An increasing number of people have therefore been forced to depend on cultivation of land, either as owners or as farm labourers. The demographic consequences of this ecological squeeze may be seen in the very low rate of population increase between 1861 and 1931, a period also punctuated by severe famines in the late 1860s and 1890s and devastating epidemics of plague and influenza in the first two decades of the twentieth century.

British rule in India tended to discourage Indians from moving into niches of resource processing and...
transport using modern technology. However, the British had gradually to modify this policy, especially when confronted with great difficulties in mobilizing India’s resources during the two world wars fought by European powers; these wars included a struggle for control over resources of the Third World. India then began to industrialize, at first haltingly, but with time at a brisker pace. As elsewhere, the trading and manufacturing concerns, working as co-operative bands as hunters did earlier, gained tremendous influence because of their access to additional sources of energy and materials. After independence, they naturally steered the course of development onto a path beneficial to them, namely an all-out state-subsidized effort to intensify the use of resources, of land, water, vegetation, minerals, and energy sources.

After independence

Such an effort has to function within severe constraints, for unlike the Europeans, who gained access to resources of new lands in their phase of industrial development, Indians are confined to a land already suffering many kinds of resource depletion. Furthermore, it is the Europeans who now have access to newer and newer resources as technological advances render useful some forms of energy and materials considered of little value earlier. India finds itself always behind in this race to create new resources through technological advances at the same time as old ones are exhausted. Consequently, the industry and commerce of the developed countries continue to keep the Indian enterprises at a disadvantage. This is reflected in the net flow of resources out of the country, whether fish, iron ore or scientifically trained manpower.

The effort at resource-use intensification has further stepped up the outflow of resources from cultivated as well as the non-cultivated land to resource processors – industry and the urban sector. This level of disruption of material cycles, which ultimately must be balanced, cannot be sustained in the long run and is leading to a continuing depression of the productive potential of the cultivated and non-cultivated lands. Thus levels of groundwater tapped for irrigation are continually falling as withdrawal substantially exceeds recharge, while large tracts of irrigated lands are becoming saline because of poor drainage. The nutrient capital of agricultural soils in tracts of intensive agriculture is nearing exhaustion and deficiencies of micronutrients are becoming more and more acute. Excessive levels of fishing by mechanized craft have led to depletion of coastal fish and prawn stocks, while the offshore stocks remain underutilized. Forest resources are being overexploited in a complex, multidimensional process. Thus, industries as well as villagers are going to localities that are farther and farther away and less and less accessible to them. They are using tree species that are increasingly less suitable for the desired purpose and chopping trees down at smaller and smaller sizes (see Table 2).

Village grazing lands have shrunk in size even as the numbers of livestock grazing on them have risen. The situation has, however, been saved from utter disaster by an inflow of irrigation water, agrochemicals and high-yielding varieties to the agricultural sector. This inflow is, however, restricted to only 20% of the land under cultivation. Nevertheless, it has succeeded in enhancing food production to a level adequate to ensure subsistence for the entire population (Figure 8).

There has thus been a remarkable, albeit limited, expansion of niche space for food production in tracts of intensive agriculture. There has also been an expansion of niche space for resource processing and transport, for information processing and for resource usurpation. However, this is offset by the continuing contraction of niche space in tracts of subsistence agriculture, and for those dependent on foraging for resources, the pastoralists, fishermen, artisans and nomads. At the same time, there has been a continual increase in the numbers of people, the population growth rates now being far higher than ever. Modern means of communication and transport have been effectively employed to forestall large-scale death characteristic of the early famines, and medical advances have checked the spread of epidemics as well as helped to suppress malaria in the areas where it is endemic. All these measures were pursued with great vigour after independence, and the resulting growth in numbers has implied mounting demands on the niche space. The consequence has been a scramble for resources and intense conflict, in the

INTERDISCIPLINARY SCIENCE REVIEWS VOL 15 NO 3 1990 221
cultural entities, with no common belief system. The change in their relationships sets them up against each other, with communal violence an all too evident result.

Prospects

India obviously needs a new strategy of resource use and a new common belief system to hold the society together and put this strategy into operation. The present strategy of resource-use intensification, leading to increasing levels of outflows from the countryside to the urban-industrial sector, which is heavily subsidised by the state, and from the country as a whole to the developed world, and the belief system centred on development and national prestige, which has replaced the unifying theme of a national struggle against the British, have proved inadequate. The new strategy has to be grounded in efficient, sustainable use of resources and supported by a belief system based on respect for the natural endowments of the country. There are welcome signs that such a strategy and such a belief system are beginning to emerge, although not enough has happened in terms of concrete action. What does ultimately happen will depend critically on how far society recognises the real power of those whose well-being is organically linked to the health of the resource base of the country - the peasants, the tribal peoples and the nomads.

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Literature cited


26. Mahabharata, Adi Parvan 19 217 ff: 63.12 ff


33. R. S. Sharma, Urban Decay in India, circa 300 to 1000 AD. Munshiram Manoharlal, New Delhi (1982).


53. S. Bhattacharya, Personal communication.


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