total elimination of sucrose, accompanied with 1% CO₂ enrichment in the nutrient medium and bright light were detrimental to growth. This clearly shows the inevitability of sucrose in the medium for hairy root cultures of S. khasianum. Sugars are involved in the differentiation of xylem and phloem elements in cultured cells. We have observed that growth and solasodine production improved at 3% sucrose, 1% CO₂ and bright light (Figures 5 b and 6). Concentrations higher than 1% CO₂ were seen to inhibit growth (Figure 5). Other research groups have reported similar decrease in secondary metabolite production in cell cultures as a result of high CO₂ concentration. Therefore, by manipulating environmental and nutritional conditions, optimum growth and solasodine production could be achieved in hairy root cultures of S. khasianum. This requires a light intensity of 2000 lux at 14 h photoperiod (14 h of light and 10 h of dark), 25°C, 3% sucrose and 1% CO₂ as seen from our results. These conditions can be used to achieve a scale up of solasodine and hairy root cultures in suitable bioreactors.


Acknowledgement. We thank CSIR, New Delhi for providing financial assistance.

Received 15 April 2004; revised accepted 19 July 2004

Assessment of habitat loss in Kameng and Sonitpur Elephant Reserves

S. P. S. Kushwaha and Rubul Hazarika

1Forestry and Ecology Division, Indian Institute of Remote Sensing, 4 Kalidas Road, P. O. Box 135, Dehradun 248 001, India
2Geography Department, Cotton College, Guwahati 781 001, India

The Kameng and Sonitpur Elephant Reserves in northeastern India are comprised of trans-border subtropical evergreen to tropical moist deciduous forests of Arunachal Pradesh and Assam. The reserves are facing deforestation and habitat loss in recent years. The present study attempts to investigate the loss of habitat in these reserves using temporal satellite imagery of periods 1994, 1999 and 2002. The on-screen visual interpretation of the three-period imagery revealed alarming and continuous habitat loss from 1994 to 2002. The overall habitat loss was found to be 344 km² between 1994 and 2002. The average annual rate of deforestation worked out to be 1.38%, which is much higher than the national average. The rate of deforestation was highest between 1999 and 2002. The study indicated that at this rate much of the forests in the study area would be depleted within the next few years. It also showed that moist deciduous forests, which possess highest biodiversity in Assam, are facing maximum deforestation. High deforestation has resulted in high man–elephant conflicts. The study suggests rehabilitation of affected forests in the larger interest of elephants and biodiversity.

For correspondence. (e-mail: spskushwaha@yahoo.com)
strategy. As human and cattle populations have demographically expanded, their demand for space and resources has increased. There are vast expansions of human habitations, agriculture and the industry at the expense of wilderness areas, especially in developing countries. The encroachment of the natural habitats is one of the most critical issues in wildlife conservation today. The consequences of an ever-increasing pressure of human development are depletion, degradation and fragmentation of habitats, loss of corridors and an increased human–animal conflict to name a few. The Government of India has taken serious note of the situation and embarked upon ambitious conservation-oriented wildlife projects such as Project Tiger, Project Crocodile, Project Hangul, etc. Project Elephant was started on similar lines in 1992, with an aim to provide the much-needed impetus to conservation of Asian elephant (Elephas maximus) in the country. Eleven elephant ranges with sizeable elephant populations have been identified for this purpose. They are: (i) Eastern India (9669 km²), (ii) North Brahmaputra (4300 km²), (iii) South Brahmaputra (4400 km²), (iv) Kaziranga (4900 km²), (v) Eastern Doors (3800 km²), (vi) Garo Hills (3500 km²), (vii) Nilgiri–Eastern Ghats (13,000 km²), (viii) South Nilgiri (2400 km²), (ix) the Western Ghats (5700 km²), (x) Periyar (3300 km²) and (xi) Northern India (3000 km²).

There are about 35,000 to 50,000 elephants in Asia, which is one-tenth of the estimated population of African elephants. The elephant is the largest terrestrial mammal in India. There is enough evidence to suggest that the elephant had wide distribution in India in the past. Today its distribution is limited to four widely separated geographical zones, viz. southern India (14,800 elephants), central India (2400 elephants), northern India (1600 elephants) and northeastern India (9200 elephants). The present estimated population of elephants in India is about 28,000, which also includes more than 3000 elephants in captivity in different parts of the country. Elephant reserves seldom contain the full range of natural resources necessary for the survival of a large elephant population and therefore migration across such reserves occurs. An elephant’s daily need for fodder is about 250–350 kg. Large animals like elephants are particularly vulnerable to habitat degradation and corridor loss as they migrate over long distances; as much as 50 km, as in West Bengal and north-eastern India or as little as 10–20 km, as in parts of Sri Lanka. Some elephant populations even visit adjoining non-forest areas such as agriculture or human habitations, despite risk of life.

The expanding geospatial technologies, viz. remote sensing, geographic information system (GIS) and global positioning system (GPS) provide the capabilities to acquire, analyse and interpret wildlife habitat information on various scales, time- and cost-effectively. According to the American Society of Foresters, satellite imagery and related technology is one of the top ten advances in forestry in the past one hundred years. Many studies have used remote sensing and GIS for wildlife habitat analysis during the past three decades. A Chinese study in Xishuangbanna clearly demonstrated the potential of integrating remote sensing, GIS and field information for habitat assessment. In Thailand, satellite imagery and GIS have been used to find out the habitat suitability for Asian elephants. IRS 1C LISS-III data were used to study the elephant habitats and corridors in Orissa and adjoining parts of Bihar. The ecological status of elephant corridors in Rajaji–Corbett area in Uttarakhand was evaluated using a combination of remote sensing, GIS and field investigations.

This study covers large parts of the Kameng and Sonitpur Elephant Reserves (KSER), spread in West Kameng, East Kameng and Papum Pare districts, Arunachal Pradesh and Sonitpur and Darrang districts, Assam and aims to present a comprehensive picture of elephant habitat loss and degradation using remotely sensed data of periods 1994, 1999 and 2002. An effort was also made to relate the changes in the habitat to the man–elephant deaths reported from the region. Our earlier study focused on Sonitpur district only and reported an overall habitat loss of 232 km² between 1994 and 2001.

The North Brahmaputra Elephant Range covers 4300 km² hill forests of Arunachal Pradesh and dooar forests of Assam on the northern side of river Brahmaputra. The KSER boundaries encompass Pakke Tiger Reserve (including Pakhui Wildlife Sanctuary), Eagle Nest Wildlife Sanctuary, Sessa Orchid Sanctuary and reserve forests of Khellong Forest Division in Arunachal Pradesh and Sonai–Rupai Wildlife Sanctuary, Nameri Tiger Reserve (including Nameri National Park), Charduar, Balipara, Nowduar, Biswanath and Behali Reserve Forests in Assam. Parts of KSER falling in Arunachal Pradesh and Assam (26°27′00″–27°07′00″N and 92°01′30″–93°27′00″E) were selected for this study (Figure 1). According to Champion and Seth, the forests in the study area are comprised primarily of subtropical evergreen, tropical semi-evergreen, tropical moist deciduous and riverain forest/grasslands. The East and West Kameng districts have 88.56% of their area under forests, while forest area in Papum Pare is 94.74%. Darrang and Sonitpur districts have 13.56 and 19.80% area respectively, under forest.
hare, yellow-throated martin, rhesus macaque, capped langur, about 250 varieties of butterflies, 300 species of birds and four species of hornbills have been reported from the study area.

The dooars or foothills in Assam adjacent to Arunachal Pradesh border provide plenty of browse material for large herbivores like elephants. This favourable habitat has been seized and deforested during the past one decade due to a peculiar socio-political problem. The area is dominated by the Bodo tribe, which has been demanding for a separate ethnic Bodo province since long. Since their demand was not met, they resorted to several movements and widespread insurgency in Bodo-dominated districts of Kokrajhar, Darrang and Sonitpur in Assam. One of the consequences of this insurgency is large-scale deforestation and encroachment in forested tracts encompassing reserve forests of Sonai-Rupai, Charduar, Balipara, Nowduar, Biswanath and Behali. Bishet has expressed doubts about the viability of KSER in the light of large-scale deforestation in the area.

Paddy is the major crop cultivated by the present-day occupants of the land. Paddy crop attracts elephants, which in turn devastate farmers’ annual food source and supplementary income. This leads to man–elephant confrontation, resulting in loss of elephant and human lives. About 60% of the elephants in Sonitpur district, Assam and adjoining East and West Kameng districts have been wiped out in the last five years; the most common method of killing is by poisoning. Ninety three persons were killed by wild elephants during 1991–2003 in Kameng–Sonitpur area. During the same period elephant deaths were 52, among which 23 were due to poisoning. In general, more humans and elephants died during 2000–03 (Table 1). Crop and property damage by elephants is worth 2.5 million rupees (US$ 55,000) per year (Talukdar, pers. commun.). Crop depredation has become a serious problem in the KSER. Presently, elephants are compressed into smaller home ranges and left with little choice for traditional seasonal migration. The resultant increase in elephant densities in the remaining parts of the KSER has lead to serious resource competition and habitat destruction. The Supreme Court of India has imposed a blanket ban on clear felling from 1996 onwards in North East India. However, felling in troubled districts like Sonitpur continues unabated.
The Landsat-TM imagery (for 1994 and 1999) and IRS LISS-III imagery (for 2002) were used (Figure 2). The two images had to be mosaiced to cover the entire study area in case of 1994 and 2002 data. Histogram matching was done to correct the radiometric differences before mosaicing. All imagery were rendered to atmospheric correction using dark pixel subtraction method. Then they were geo-referenced to toposheets and to each other to obtain high geometric fidelity. The preliminary on-screen visual interpretation of the three-period imagery was carried out to delineate different forest (also referred as habitat here) and non-forest types using ERDAS IMAGINE and ArcGIS. A field visit was made for twenty days to correlate the image characteristics with forest and non-forest categories. A GPS set was used to facilitate ground truthing. Modifications in the interpretation were made after field visit and maps were finalized. The visually interpreted maps were converted to shape files for change detection in GIS environment. Intersect operation was used to generate change maps for the three periods. Information on deaths due to man–elephant conflict was collected from Aranyak, a non-governmental organization at Guwahati, Assam. Information on biodiversity was taken from our earlier work on biodiversity characterization at landscape level in northeastern India.

Four types of elephant habitats were identified and mapped from satellite imagery: (i) subtropical evergreen forest, (ii) tropical semi-evergreen forest, (iii) tropical moist deciduous forest and (iv) grasslands, distributed from hills (up to 1000 m elevation) to plains (Figure 3). The species composition of these forest types could be found in an earlier study on Sonitpur. The moist deciduous forest is located mostly in the plains. The semi-evergreen forest represents the ecotonal zone between moist deciduous and evergreen forests. The moist deciduous forest was noticed to have suffered maximum loss from 1994 to 2002 through 1999. The loss, however, was more pronounced between 1994 and 1999 (226.76 km²) than between 1999 and 2002 (118.32 km²).

The total loss of this category of forest worked out to be 345.08 km² (or 45.38%) between 1994 and 2002. The semi-evergreen forest too suffered a loss of 20.44 km² between 1994 and 1999. No worthwhile loss was recorded between 1999 and 2002. There was no loss of subtropical evergreen forests, except that 5.55 km² got converted into open/degraded forest category.

The results indicate that forest areas in the immediate vicinity of human habitations suffered the most compared to those located away. Nearly all deforestation took place towards the Assam side of the inter-State boundary. The change of 5.55 km² dense forest into open forest inside Arunachal Pradesh could be attributed to shifting cultivation and not due to the Bodo problem. The degraded semi-evergreen forest decreased by about 12 km² between 1994 and 1999. Degraded deciduous forest increased considerably due to conversion of dense forest–61.23 km² between 1994 and 1999 and 20.50 km² between 1999 and 2002.

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<table>
<thead>
<tr>
<th>Year</th>
<th>Persons killed by wild elephants</th>
<th>Natural death of wild elephants</th>
<th>Elephant death by poisoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991–92</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1992–93</td>
<td>11</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1993–94</td>
<td>12</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td>1994–95</td>
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<td>1</td>
<td>–</td>
</tr>
<tr>
<td>1995–96</td>
<td>6</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>1996–97</td>
<td>4</td>
<td>3</td>
<td>–</td>
</tr>
<tr>
<td>1997–98</td>
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<td>–</td>
</tr>
<tr>
<td>1998–99</td>
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<td>8</td>
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</tr>
<tr>
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<td>–</td>
</tr>
<tr>
<td>2000–01</td>
<td>10</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>2001–02</td>
<td>15</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>2002–03</td>
<td>19</td>
<td>–</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
<td>29</td>
<td>23</td>
</tr>
</tbody>
</table>

Figure 2. Satellite imagery (FCC) of (a) 1994, (b) 1999 and (c) 2002.
2002 – thus showing an overall increase of 40.73 km² from 1994 to 2002. The 6.23 km² grasslands area was altogether lost between 1994 and 1999. The reserve forest-wise loss of habitat was found to be maximum (90%) in Nowdur RF followed by Biswanath RF (70%), Charduar RF (60%), Balipara RF (40%), Sonai–Rupai RF (30%) and Behail RF (10%) in that order (Figure 4). An analysis of the overall depletion and degradation of forests showed alarming trends. While about 344 km² area under different forest types was lost between 1994 and 2002, the decrease was much higher in case of moist deciduous forests. Being interface forests, deciduous forests suffered continuous depletion with the passage of time (Table 2). The results reveal an average annual deforestation rate of 1.38%, which is rather too high. The annual rate of deforestation worked out to be higher between 1999 and 2002 (1.59%) than between 1994 and 1999 (1.31%). The above results indicate that forests are under massive destruction with time and the elephant habitat is decreasing day by day.

The KSER forests historically represent the relatively undisturbed dense climatic climax forests and are located in the East Himalaya biodiversity hotspot of the country. Our study on biodiversity estimated high plant species diversity in evergreen, semi-evergreen and moist deciduous forests of Assam. Highest number of species, genera, families and Shannon–Weaver index of diversity was reported in moist deciduous forests, followed by evergreen and semi-evergreen forests in that order. The degraded forests also showed high species diversity, which indicates that disturbance level till then was not high. The grasslands

### Table 2. Habitat changes in KSER

<table>
<thead>
<tr>
<th>Forest type</th>
<th>Area (km²)</th>
<th>Habitat loss/gain (km²)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtropical evergreen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dense Open/degaded</td>
<td>1319.78</td>
<td>1314.23</td>
<td>1314.23</td>
<td>-5.55</td>
</tr>
<tr>
<td>Tropical semi-evergreen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dense Open/degaded</td>
<td>977.67</td>
<td>957.23</td>
<td>957.00</td>
<td>-20.44</td>
</tr>
<tr>
<td>Tropical moist deciduous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dense Open/degaded</td>
<td>620.48</td>
<td>533.72</td>
<td>415.40</td>
<td>-226.76</td>
</tr>
<tr>
<td>Grasslands</td>
<td>6.23</td>
<td>0.00</td>
<td>0.00</td>
<td>-6.23</td>
</tr>
<tr>
<td>Non-forest</td>
<td>4120.16</td>
<td>4324.59</td>
<td>4464.06</td>
<td>204.43</td>
</tr>
</tbody>
</table>

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had least diversity. A total of 640 species from moist deciduous, 300 from evergreen and 250 from semi-evergreen forests were recorded (Figure 5). It is unfortunate that the forest having highest diversity is being lost with the highest rate.

The once vast home ranges of the elephant are now being depleted, degraded and fragmented into smaller habitat islands due to intense pressure on such ranges in many wildlife habitats of India, and elephant habitats are no exception. A wide-ranging animal like elephant requires vast areas for fodder and healthy survival. The compression and fragmentation of the habitat leads to lesser availability of fodder, increased risk of poaching and inbreeding among various elephant groups. Some elephant reserves like KSER are shrinking so fast that elephants may not even get sufficient time to get used to it. Elephant groups have been noticed roaming in the area, especially during night, even after the habitat is deforested. A possible reason for their continued use of the habitat even after deforestation could be their liking for paddy crop growing in their habitat. Elephants are also attracted by the country wine prepared from rice by local people. Either way they risk their lives and often get killed. As clear from Table 1, a correlation was noticed between deforestation and the number of human and elephant killings. The number of people killed during 2000–03 has constantly increased. The number of elephants killed rose sharply during 2001–02, which coincides with the maximum deforestation phase. More humans were killed by elephants than vice-versa.

Restoration of the habitat seems to be the only solution for any effective elephant conservation and human–wildlife conflict mitigation. This should be possible through rehabilitation of forests. Any further deforestation and encroachment in the KSER should be effectively resisted. The two reserves should be regularly monitored in future using remote sensing to detect the loss of the habitat due to human activities or natural calamities. The study demonstrates high potential of remote sensing and GIS technologies for wildlife habitat monitoring.

Figure 4. Habitat loss during (a) 1994–99, (b) 1999–2002 and (c) 1994–2002.

Figure 5. Species richness in the area.

Ca and Sr dynamics in the Indo-Gangetic plains: Different sources and mobilization processes in northwestern India

Jayant K. Tripathi1,*, Barbara Bock2, V. Rajamani1 and A. Eisenhauer2

1School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110 067, India
2IFM-GEOMAR, Leibniz-Institut für Meereswissenschaften, Wischhofstrasse, 1-3, D-24148 Kiel, Germany

The leachable fraction of the sediments from the Thar Desert fringe and the adjacent Ganges alluvial plains, has been studied to determine the sources and the processes responsible for the mobilization of Ca and Sr using Sr isotopes and Ca/Sr ratios. In the desert the leachable fraction of the soil/sediments is probably derived from mixing of old marine carbonates, microfossils with the sea-spray of the Arabian Sea and rainwater. Aeolian reworking of soil carbonates of this mixed origin could have provided the carbonate found at the desert fringe. The sub-humid zone of the Gangetic plains, just outside the desert fringe, has relatively higher 87Sr/86Sr ratios with lower Ca/Sr ratios, indicating silicate weathering as the major contributor of leachable fraction. The spatial geochemical differences could also be related to the ineffectiveness of dust transport and accumulation processes in the humid Ganga plain. The 87Sr/86Sr ratio of the present-day dust leachate from the polluted city of Delhi indicates that its Sr source is petroleum burnt residues.

We studied the sediments of the Thar Desert and Ganga plains for their sources and found that the Himalayas have been playing a dominant role in supplying sediments for these two geomorphic entities. During the course of the Sr and Nd isotopic studies of the sediments, we leached our samples with dilute hydrochloric acid to separate carbonates and other authigenic phases from the samples20-22. Besides studying silicate chemistry, we also analysed the leachates for their 87Sr/86Sr isotopic composition. Because Sr replaces Ca in mineral structure, it can be used as a tracer for the source of Ca. When we combine this information with Ca/Sr ratios of the leachates, we find that we have a powerful tracer pair to distinguish between different sources for the leachates. Such a geochemical approach can provide important information on the sources of calcium in various surface and ecosystem studies as shown by various investigations8-9.

The main sources which may supply Ca to the ecosystem could be weathering products of silicates and carbonates, sea spray and rainwater8-9. Besides the local sources, dust derived from a long distance could also provide Ca to the

Acknowledgements. We thank Dr V. K. Dadhwal, Dean, Indian Institute of Remote Sensing, Dehradun for the encouragement and opportunity. We also thank Dr B. K. Talukdar, Secretary General, Aranyak, Guwahati for providing data on human and elephant deaths.

Received 12 February 2004; revised accepted 30 July 2004

*For correspondence. (e-mail: jkttrip@yahoo.com)