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Visualization in biodiversity research: A case study of Mehao Wildlife Sanctuary, Arunachal Pradesh, north-east India

S. Narendra Prasad, B. Prabakaran* and C. Jeganathan**

Sálim Ali Centre for Ornithology and Natural History, Kalampalayam, Coimbatore 641 010, India
*Regional Remote Sensing Service Centre, Dehara Dun 248 001, India
**Indian Institute of Remote Sensing, Dehra Dun 248 001, India

Biodiversity visualization is a process by which diverse data sources varying from cover types, habitats to species inventories are integrated into a single computer environment. The integration affords a far better degree of spatial reasoning and understanding of biodiversity issues than hitherto attended to. We attempt here to integrate satellite data, digital elevation models derived from the toposheets, slope, aspect, elevation data and known information on some elements of biodiversity. The visualization tools were applied for a case study in Mehao Wildlife Sanctuary, north-east India, a global hotspot of biodiversity. The thematic features included in the visualization are habitats classified using the Landsat thematic mapper (TM) data, plant succession, hotspots of plant diversity, pheasant and takin habitat. The results were 'field tested' for acceptance among the user community. It is concluded that the visualization has a substantial role in furthering biodiversity conservation.

SCIENTIFIC visualization is defined as 'the study, development and use of graphic representation and supporting techniques that facilitate visual communication of knowledge'[1]. The major objective of scientific visualization techniques is to process digital images to produce a simulated model leading to enhanced information content in the images[2]. Biodiversity visualization is a means to achieve cognizance of spatial observations of biological diversity at many scales. This is usually achieved using computer-based scientific data visualization tools[2]. Data visualization tools range from simple statistical bar charts to totally-animated realistic visual simulation and are intended to assist in the data-to-environment translation process. While this process of translating different states of environment into data and statistics exist, the converse of translating data to environmental images is less developed and often neglected[3]. The term biodiversity visualization denotes integration of diverse data sources on biological diversity – ranging from cover types, habitats, species inventories, birds and mammal vocalizations and so on into a single computer environment[3]. In the context of biodiversity research, the chief goal for data visualization lies in achieving accurate and verifiable representation of existing and projected environmental scenarios[2]. The rationale for pursuing visualization is that it aids the scientist with better tools to grapple with the complex issues on patterns of distributions of species, ecosystems and landscape. The manager and policy makers likewise can readily comprehend the issues for day-to-day management. In this paper, we present a case study of data visualization in biodiversity research in north-eastern India, a globally recognized hotspot of biodiversity. The goal is to demonstrate use and integration of digital satellite data, digital elevation models, spatial terrain analyses such as slope, aspect and known information/data on vegetation, mammals and birds. We demonstrate in particular the use of GIS overlay analyses to derive vegetation vulnerable to change, hotspots of plant diversity, pheasant habitats and habitats of rare and endangered mammal, takin.

The study area (28° to 28°15'N Lat., 95°45' to 95°50'E Long.) comprises 281.5 km^2 of lesser Himalayas of north-east India in the Dibang Valley district of Arunachal Pradesh. This area has been declared as wildlife sanctuary and is being managed for conservation of the unique values of biological diversity. Amongst the most notable features of this sanctuary is an altitudinal gradient spanning from a few hundred (500) to a few thousand (3300) metres of elevation, resulting in a variety of habitats, ecosystems and species. The habitats include tropical broad-leaved evergreen forests harbouring India's only ape, the Hoolock Gibbon and conifers in the higher altitudes, housing the endangered Red Panda. Blyths Trogopon has recently been discovered in the sanctuary. Medicinal plants such as *Taxus baccata* and *Coptis teeta* occur and are extensively used by locals.

There are no published accounts on historical land use of this sanctuary. From the anthropological descriptions of various tribes and their customs[4–6], it appears that there are no elaborate land laws nor any regulation of land use. The recent commercialization of timber from the forest gave a great impetus for both legal and illegal removal of timber from all accessible regions of the sanctuary. This is especially so in the lower (>1000 m) and mid (1000–2000 m) altitudes. The consequence of this exploitation has resulted in large-scale changes in vegetation. For example, it was observed that there is an increase in secondary vegetation and large-scale growth of bamboo. There seem to be discernible patterns of vegetation succession. For example, the cool northern aspects (the direction of slope, e.g. north, south, west, etc.) in the lower and mid-altitudes harbour *Musa* sp. and the southern aspects are often covered by bamboo and other deciduous vegetation. In the higher altitudes, the temperate evergreens dominate. Wherever disturbance is extensive, high altitude bamboo (*Schizostachyum* sp.) occurs widely. The alpine areas are located in altitudes exceeding 3200 m. The tree line is much closer (3000) to the alpine localities, compared to that of Western Himalayas.

Landsat TM digital data in bands 2, 3, 4 and 5 for 23 December 1993 were acquired for the study. The Survey of India (SOI) toposheets 91D04 and 82P16 covered the area of interest. Extensive field work in 1995 and 1996 provided the data for 'ground truth' and validation of remote sensing analyses and GIS modelling. The field work consisted of a) sampling tree, shrub and herb species composition at various altitudinal zones in 0.1 ha plots; b) sampling avian diversity in the same plots; c) obtaining ancillary information from the tribals on the distribution and abundance of pheasants and takin and; d) validation of the results.

For the entire study area, contours from SOI toposheets at 200 m interval were digitized in EASI/PACE environment on IBM RS6000 workstation at the Regional Remote Sensing Service Centre, Dehra Dun.

Digital Elevation Model (DEM) was created by the Morphology Dependent Interpolation Procedure (MDIP)[7] in GRID interpolate (GRID INT) utility of EASI/PACE. Within GRID INT the CONIC option used as diagonal methods was found to be less satisfactory. The utility, PSGIMG (Image perspective) in Terrain Analysis module was used to obtain the terrain model from the DEM.

A rectification procedure for earth rotation effect in the satellite data for bands 2, 3, 4 and 5 was done using various utilities in the module of geometric correction. Necessary Ground Control Points (GCP) were taken from the SOI toposheets. An accuracy of 2 pixels only could be obtained as there have been substantial changes in river, road junctions and even the courses of river/streams. There are very few roads to specify precise GCPS. In terms of physical limits, the accuracy represents a ground area of 0.18 ha since each TM pixel is of 30 × 30 m size.

A False Colour Composite (FCC) was generated using bands 5, 4 and 3. The sanctuary boundary was digitized on to the rectified data and all further analyses were confined to this locality only.

The DEM was used in obtaining aspect (ASP) and slope (SLP) images of the sanctuary. Two utilities, ASP and SLP in the module of terrain analysis were used to obtain the above images. The two, along with elevation images, represent important habitat variables for biodiversity research.

The multi-layer modelling routine in EASI/PACE, permits a user-defined modelling approach. This involves specifying the precise nature of model and the computational procedure. GIS raster modelling was done to 1) locate hotspots of plant diversity; 2) vulnerable areas of vegetation change; 3) pheasant habitat suitability and 41 potential takin habitats.

The resulting images from the GIS raster modelling were draped onto the DTM in FLY! programme of EASI/PACE. The entire area was traversed at varying view angles, altitudes, magnification and at different locations. The resulting visualization afforded 1) better method of locating 'ground truth' samples for classification and 2) verifying the accuracy of various classification schemes adopted.

The false colour composite draped onto DTM is given in Figure 1. An unsupervised classification was done by *k*-means classifier. The classifier is essentially a clustering algorithm computing sample means through an iterative procedure[7]. The recruiting theme map provides each cluster with a specific grey value. A total of 36 spectral classes were obtained. With the help of ground

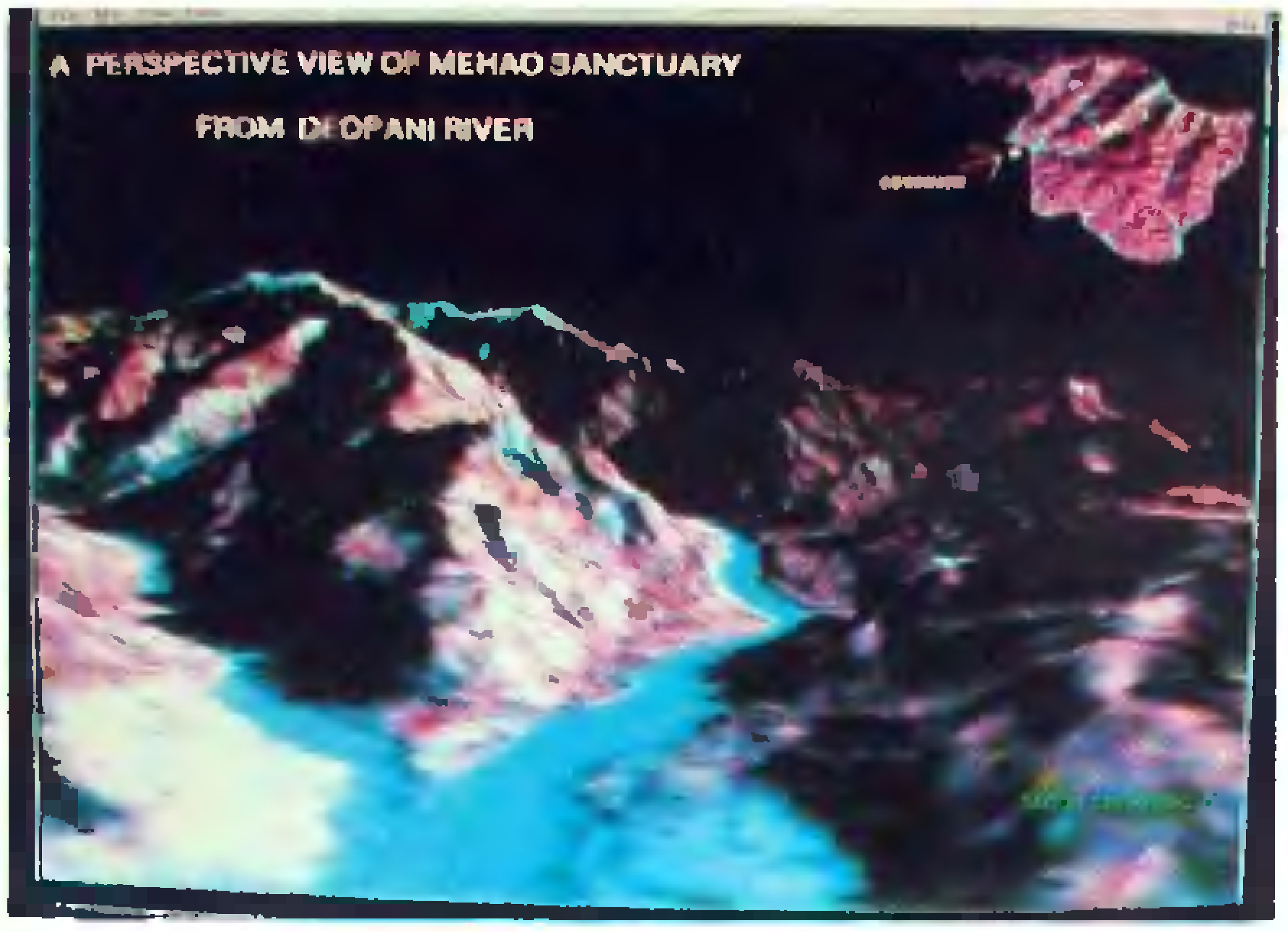

Figure 1. An FCC of TM bands 5, 4, 3 of Mehao Sanctuary, draped on Digital Terrain Model (DTM). The two rivers in the foreground are tributaries of Deopani river. The snow-capped mountains are at the rear. A two-dimensional FCC of the locality is in the inset.

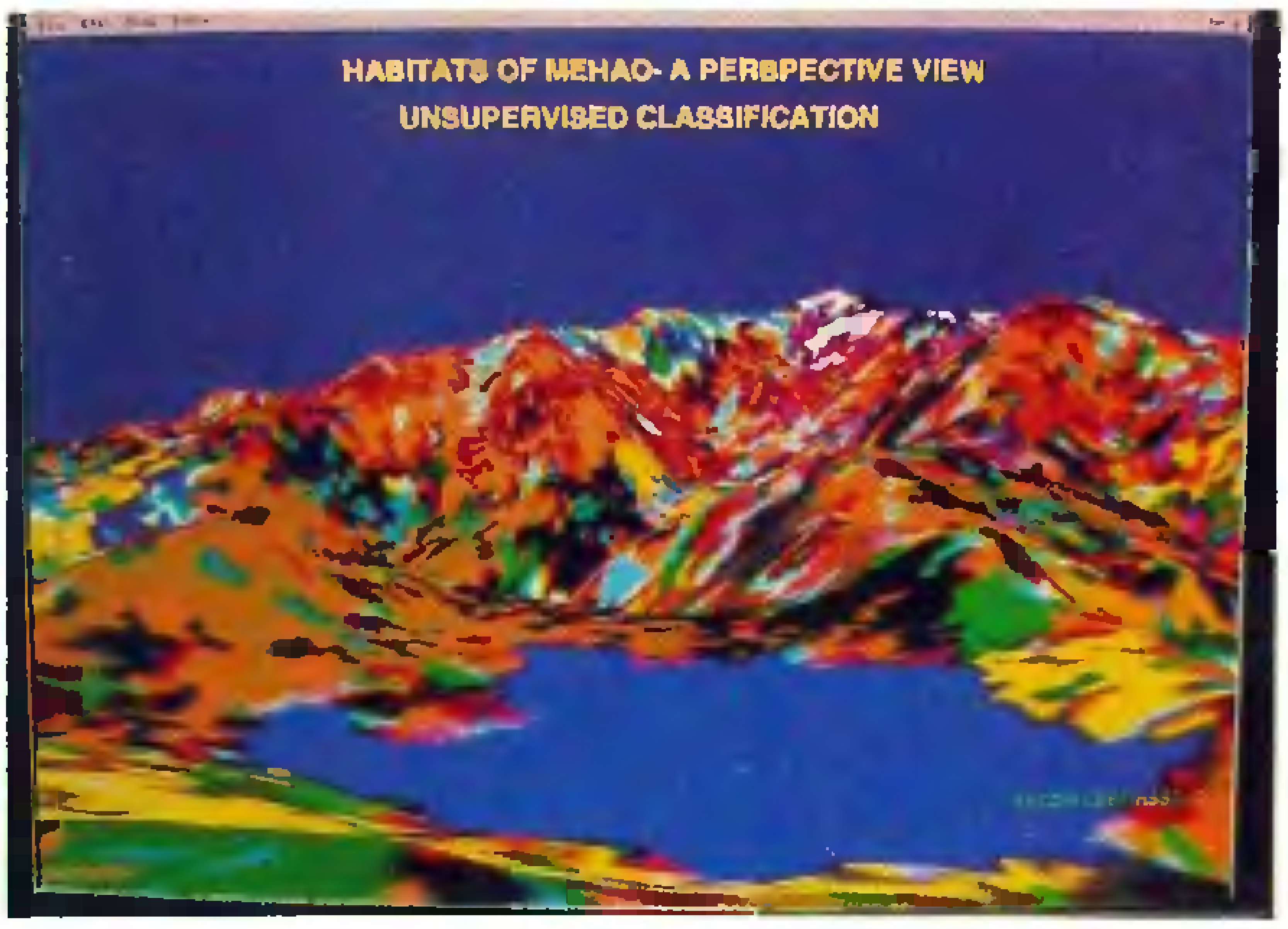

Figure 2. An unsupervised classification of TM bands 2, 3, 4, 5 gave broadly identifiable paterns of biomes. The various hues depict different spectral classes corresponding to habitat categories. In the foreground of the picture lies Mehao lake, a major landmark.

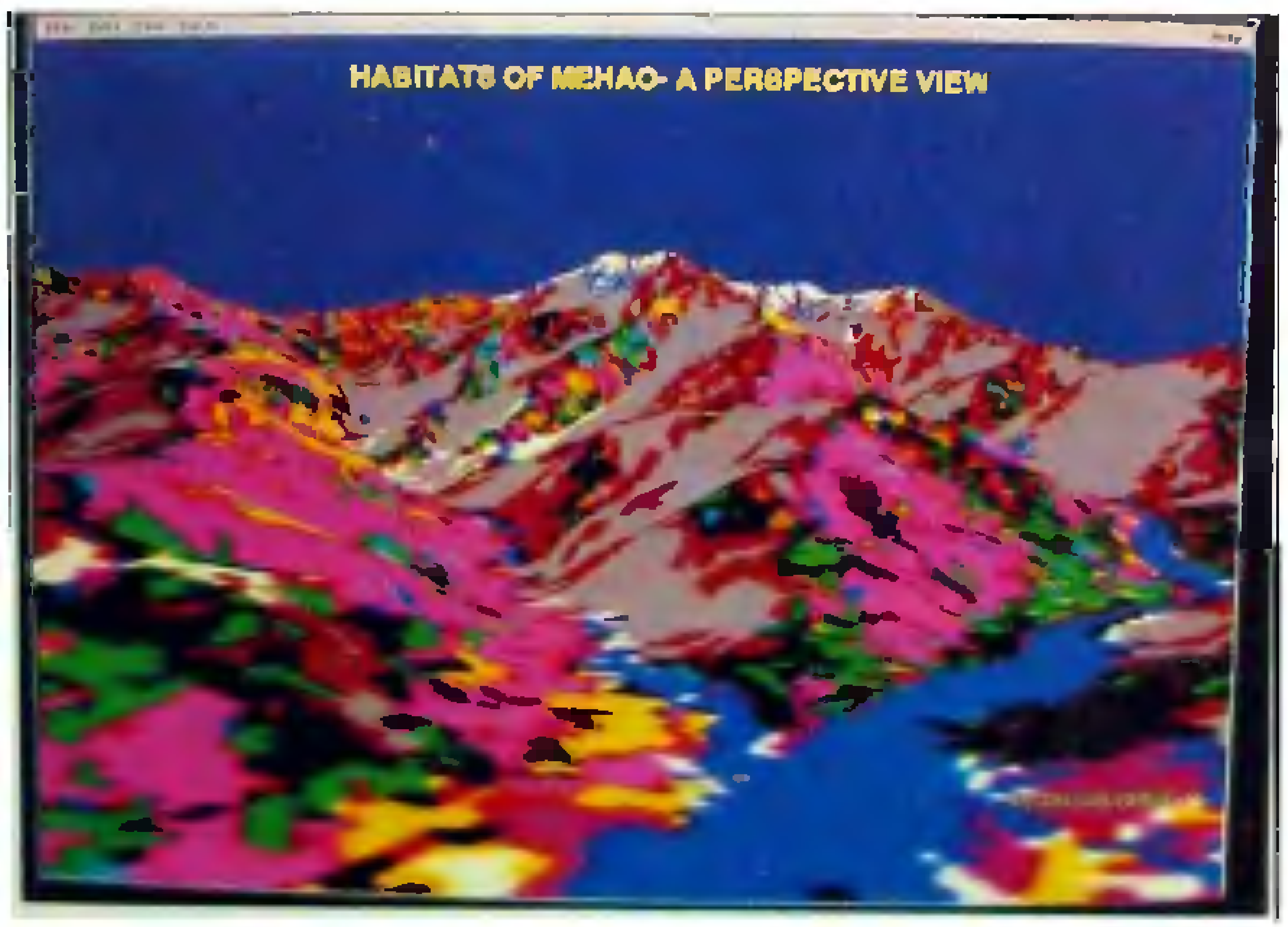

Figure 3. A supervised classification of TM bands 2, 3, 4, 5 resulted in the identification of eight major habitat categories including shades caused by high relief (shown in grey). The snow-capped mountain ridge is seen in the background.

Figure 4. The thematic layers of habitat categories were analysed along with slope, aspect and elevation layers to identify vulnerable areas of vegetation changes.

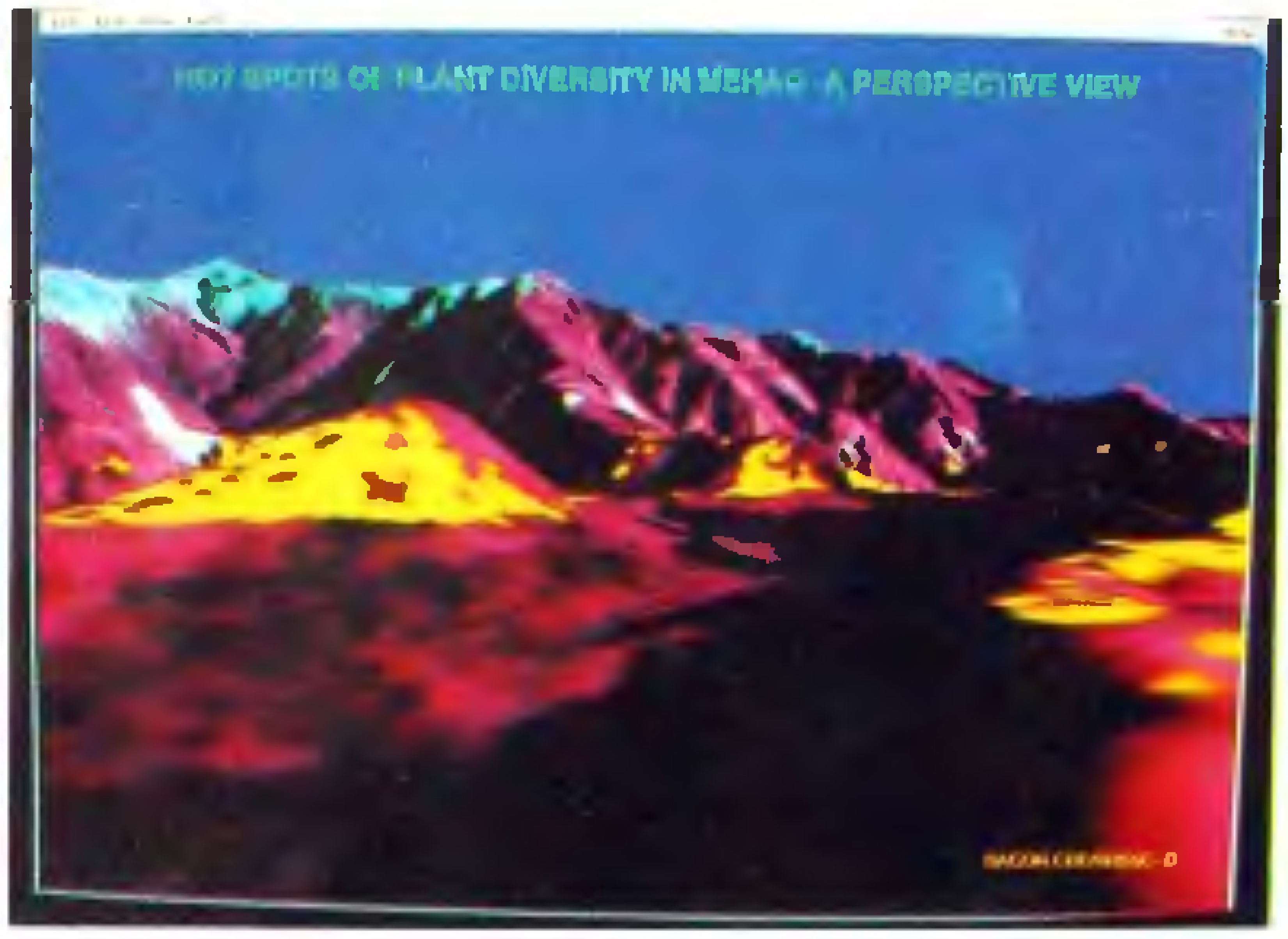

Figure 5. The results of field sampling on plant diversity were overlaid on physical attributes such as slope, aspect and elevation to obtain 'hotspots' of plant diversity. The yellow patches in the picture show these localities.

truth samples, these classes were later coalesced into 12 categories. The results were draped on DTM and are shown in Figure 2. There is abundant heterogeneity in the classes obtained. However, the high altitude habitats can be demarcated easily from the lower altitude habitats.

A supervised classification was done using maximum likelihood classifier. The accuracy of the classification was found to be only 80%. Again, a substantial extent of heterogeneity appears to contribute to the somewhat low accuracy. A thorough field check confirms the heterogeneity in small spatial unity. The results of supervised classification draped on DTM are shown in Figure 3.

The GIS models used were of necessity simple in nature. This is due to the fact that there are no ecological

Figure 6. Pheasant habitats in the altitudinal range of 800–2000 m were identified and are shown in green colour.

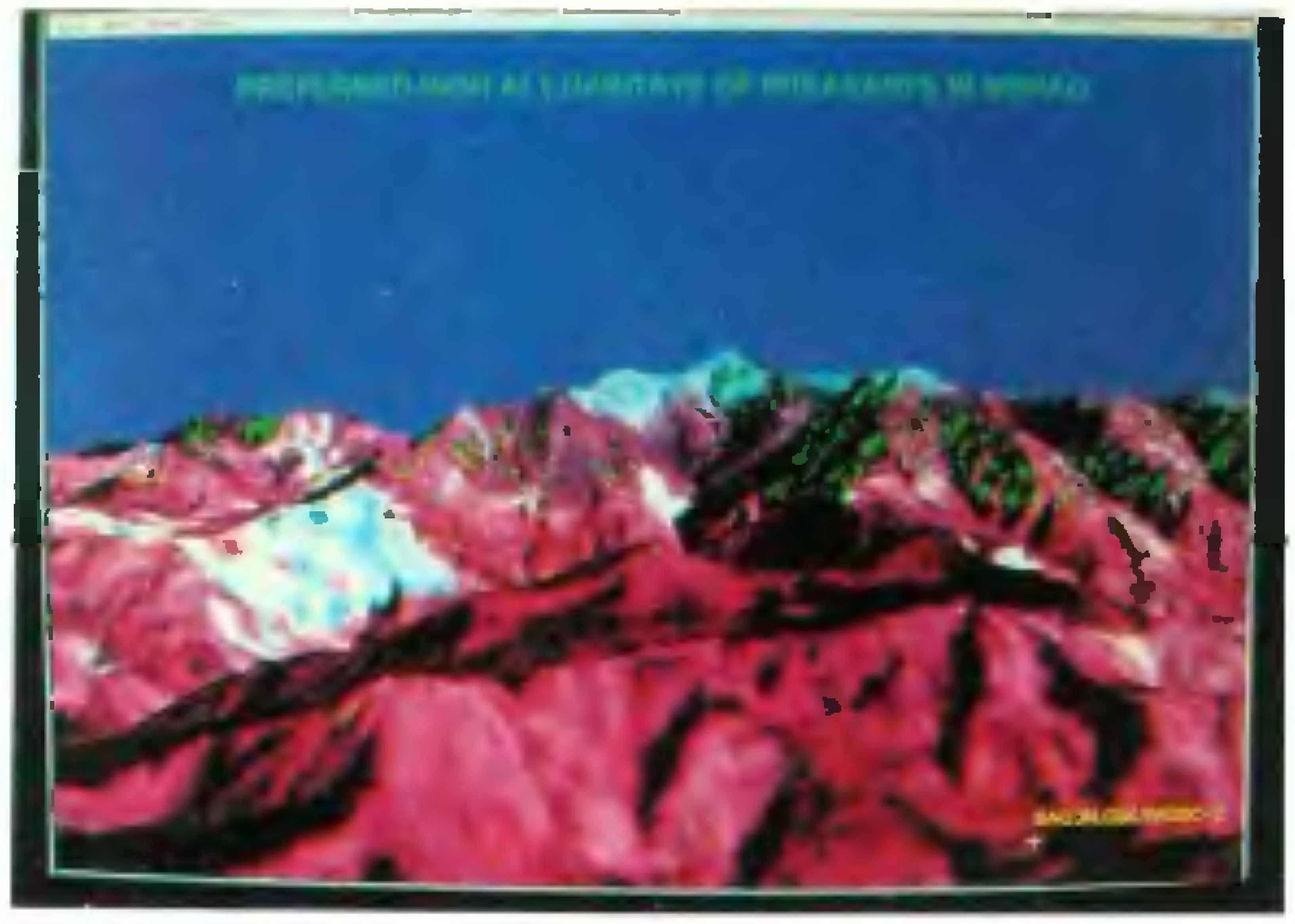

Figure 7. The preferred high altitudes of pheasants were identified using overlay analysis and the results were draped in DTM. The localities in green colour indicate these habitats.

Figure 8. Takin, an endangered mammal, occurs in sparse numbers. The likely locality of occurrence are shown in yellow colour.

and natural history studies in this area which could shed light on plausible models to be used. Since physical variables such as elevation, slope and aspect are important determinants of distribution of vegetation/habitat categories, these variables were used in four thematic features of relevance to biodiversity. It is to be pointed out that this is obviously an illustrative attempt and not comprehensive.

It is known that vegetation is vulnerable to change due to human activity. This is especially so in the south-facing accessible slopes (<30°) with deciduous vegetation. Southern aspects by virtue of their longer duration of exposure to harbour, dry habitats with serial stages prone to change. In the overlay these conditions, e.g. deciduous vegetation on southern and south western aspects with slopes of less than 30° with altitude of less than 1800 m were specified. The percentage pixels qualifying these criteria was found to be only 2.83. The total area is 795 ha. However, spatially speaking, these locations are spread over the entire area. The results were draped onto the DTM (Figure 4).

From the field sampling on plant diversity, it appears that northern aspects with evergreen vegetation are likely candidate sites for hotspots. The hotspots are those that have highest species richness in the field samples. These were located by specifying masks for slope, aspect, elevation and vegetation themes. The mask size is 281.5 km^2. The percentage of pixels qualifying these conditions is 0.84. Hence, the total area under hotspots is 236 ha. A part of the hotspots draped on DTM is given in Figure 5.

This area is known for its pheasants. Blyth's tragopan, a highly endangered pheasant is routinely hunted. From the available information on habitat preferences of pheasants between 800 and 2000 m altitude, using the thematic covers of vegetation, slope, aspect, an overlay analysis indicated 1.4% of the geographical area as suitable habitat. This works out to be 393 ha. The area is shown in Figure 6.

At higher altitudes (>2000 m), the winter habitat of pheasants is largely restricted to south-facing slopes. An overlay analysis using southern aspects with evergreen, semi-evergreen vegetation cover themes indicated 0.57% area as suitable habitat. This works out to be 150 ha spread over the entire area (Figure 7).

Takin, the largest representative of Rupicaprinae of the Bovidae inhabits some of the steepest mountains in mid-altitude tropical evergreen forests (90°–1200 m). It has a narrow range of global distribution, being confined to a few patches in Bhutan, part of China and parts of Arunachal Pradesh[8].

Takin, is therefore a flagship species of biodiversity in Mehao and is an extremely rare mammal to be encountered. However, the hunters appear to hunt these animals (which only points to the extent and depth of their knowledge on environment). From detailed description of the preferred habitat, using overlay analysis of slope, aspect, elevation and vegetation classes, we obtained the preferred habitats of Takin (Figure 8). The preferred habitat constitutes just 0.11% of the sanctuary. In real terms the extent is a mere 30 ha. This is possibly the major reason for the observed low encounter rates. It also points to the need of including available habitat outside of Mehao in a bigger viable conservation unit.

Visualization in biodiversity research entails a whole spectrum of potential benefits at the levels of species, ecosystem and at landscape. An explicit spatial dimension – in terms of patterns of distribution of the above three components of biodiversity, can be provided. This is especially useful in underexplored and relatively unknown field locations using simulated environmental images. The Rapid Biodiversity Assessment (RBA) procedures stand to gain immensely by using visualizing tools. As a sequel to RBA one could effectively use the visualization for evolving comprehensive and appropriate sampling designs for biodiversity description, assessment and monitoring.

For the routine natural history surveys of endangered rare species, one can use available information, howsoever meagre, along with visualization tools to focus the surveys in well-defined geographical locations. Such focused surveys of course, are not only cost effective but could contribute to better formulation of habitat suitability models for a number of species.

We thought it would be better to elicit reaction to these visualizations and perceived impressions on utility for field personnel. We have shown these and the two-dimensional photos to a wide group of people in the sanctuary. It was amazing to find the ease with which the people identified ground features draped on DTM. These persons could identify vegetational and terrain features much more easily and preferred the three-dimensional pictures.

The results on visualization can be altered/improved based on availability of further field data or models of habitat utilization of species of interest. Again, in the area of EIA studies, these visualization tools hold great promise in communicating the data in the form of environmental images to a wide group of users.

In conclusion, we hold the opinion that this methodology and its applications will find wider use in the coming years. This will undoubtedly go a long way in baseline information collection, assessing and monitoring biodiversity in ever-changing environment.

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Transient expression of β-glucuronidase reporter gene in embryogenic callus cultures of an elite indica basmati rice (*Oryza sativa* L.)

D. Minhas*, S. Bajaj[§], A. Grover* and M. V. Rajam[§†]

Departments of Genetics[§] and Plant Molecular Biology*, University of Delhi, South Campus, Benito Juarez Road, New Delhi 110 021, India

Various parameters for the introduction of β-glucuronidase (GUS) reporter gene driven by actin-1 promoter into embryogenic callus cultures of an elite indica basmati rice cultivar (Basmati 370) through biolistic delivery method were studied. Helium gas pressure of 900 psi, arrangement of the callus at the centre of the plate or 1100 psi helium pressure and arrangement of the callus at the innermost concentric ring of the plate along with 6 cm distance from the microcarrier produced best results in terms of transient GUS expression, but with moderate callus survival. However, better survival of the callus with moderate GUS expression was observed when the callus was placed at the centre or the innermost concentric ring of plate with a distance of 9 and 6 cm using 900 and 1100 psi, respectively; and these parameters may be useful in recovering transgenics. These parameters will now be employed for the development of fertile transgenic basmati rice harbouring agronomically useful genes.

SIGNIFICANT progress has been made in the last two decades in the improvement of important cereals, such as rice, through conventional breeding methods.

[†]For correspondence.