$$2\tau_2 = \frac{2c}{g}\sqrt{\left(1+\frac{gx_2}{c^2}\right)^2 - \left(1+\frac{gx_1}{c^2}\right)^2}. \quad (12)$$

Using eq. (9), this can be written as

$$2\tau_2 = \left(1+\frac{gx_2}{c^2}\right)\frac{2v}{g}. \quad (13)$$

In the limit of infinitely great acceleration, we get

$$2\lim_{g\to\infty}\tau_2 = \frac{2vx_2}{c^2}. \quad (14)$$

Since $x_2 = l_0$, the total ageing of A as calculated by B is $2(l_0/v - vl_0/c^2) + 2vl_0/c^2 = 2l_0/v$ in agreement with A's own prediction.

Unnikrishnan has argued that Einstein's resolution of the twin paradox contains 'logical fallacies' and 'physical flaws'. In this communication I have shown that the reason for these conclusions are that Unnikrishnan has made some errors in his applications of the theory of relativity to different versions of the twin paradox. This has also led him to conclude that most earlier analyses of this paradox are untenable, although they are, in fact, correct.

1. Unnikrishnan, C. S., On Einstein's resolution of the twin clock paradox. *Curr. Sci.*, 2005, **89**, 2009–2015.
2. Grøn, Ø., *Eur. J. Phys*., 2006, **27**, 885–888.
3. Eriksen, E. and Grøn, Ø., *Eur. J. Phys.*, 1990, **11**, 39–44.

Ø. G. GRØN

Oslo College, Department of Engineering, P.O. Box 4, St. Olavs Pl., 0130 Oslo, Norway
Institute of Physics, University of Oslo, P.O. Box 1048, Blindern, 0216 Oslo, Norway
e-mail: oyvind.gron@iu.hio.no

Degradation of Himalayan forests

On the basis of only one satellite scene which covers 20,000 sq. km area and does not fully cover Almora and Pithoragarh districts, Prabhakar *et al.*[1] have tried to draw conclusions on the degradation of forests in the entire Himalayas and criticized the estimates published by Forest Survey of India (FSI) in the State of Forest Report (SFR) 1999. FSI has undertaken monitoring of the forest cover of the entire country on a regular two-year interval since early 1980s.

It appears that the authors have not read the SFR 1999 of FSI carefully. The methodology followed by FSI in the forest cover assessment has been clearly mentioned in the report (pp. 2, 3).

The authors have used the satellite imagery of IRS-ID LISS III of 31 May 1998. It is well known that the month of May is the culmination of dry season in northern India and even some of the evergreen trees like pine (*Pinus roxburghii*), which is a major species in the study area, shed major portion of their leaves (as referred by Troup 1921). The ground is dry. Even if there are a few showers of rains in May (we checked the rainfall data from India Meteorological Department) in the hills, interpretation of the satellite data is bound to give a degraded look of the forest. For example, if a scientist assesses the forest cover of an area having dense moist/dry deciduous forest using satellite data of dry season (April/May), he may conclude that there is no forest in the area or it is highly degraded. Our experience shows that not only the reduced foliage/chlorophyll on the tree, even moisture stress affects the signature in the sensor. For monitoring the forest cover of the country, FSI procures cloud-free data from NRSA for the period from October to February, so that the correct reflectance of the tree having full crown and chlorophyll content is registered. In this case, FSI has used data for the said area for the period November 1996.

The authors have made a comparison of their findings with the FSI using (%) values and not absolute area figures. About 25% area of Pithoragarh district has been left out by the authors, which is under snow and in the nonforest category; whereas FSI has used the entire area of the district in the assessment. As area of the district goes in the denominator for working out forest cover percentage, comparing such percentages becomes incorrect.

The authors have not defined the 'forest', which is the key parameter of the study. The procedure to classify the degraded forest which is below 40% of canopy density and inclusive of scrub, has also not been described. On the other hand, FSI follows the standard international classification for canopy density. Scrubs having canopy density less than 10% are categorized as 'nonforest' by FSI. If the scrub is included in the degraded forest area, the percentage of the degraded forest would obviously be inflated. The most glaring inconsistency is in table 3. The total forest cover, including scrub, is 72% in Almora, whereas FSI has estimated it as only 48%. The additional 24% area of forests estimated by the authors seems to be due to the definition adopted by them. It appears that even grasses have been included in the forests, which have been subsequently categorized as degraded forests. Obviously, when this huge area of nonforest is included in the total forest area, the percentage of degraded forests in the total forest will increase accordingly. Comparisons of degradation as shown in table 3 are therefore unscientific.

It is to be appreciated that there is a difference between a study undertaken for research purpose and the one for state and national level planning. Mention of the confident intervals is more relevant when a study is for research purpose. In the estimates which are derived for a state and national level planning, confident intervals are not quoted. FSI has described the full method of estimation of error in SFR 2001 based on statistically sound principle.

Digital image processing was introduced in FSI in 1990s and became operational only in the year 2000. FSI results used by authors for comparison are based on visual interpretation of 1 : 250,000 scale images having minimum cartographic limit of 25 ha. The two datasets are therefore not comparable. If the authors were interested to make a scientific comparison of findings of their study with the results of those of FSI, it would have been appropriate to use SFR 2001 or SFR 2003 of FSI, which are based on digital processing of comparable datasets.

1. Prabhakar, R. *et al.*, *Curr. Sci.*, 2006, **91**, 61–67.

D. PANDEY

Forest Survey of India,
Dehradun 248 195, India

I read the article by Prabhakar *et al.*[1] with keen interest, fully aware of the technical challenge and public sensitivity on the subject. I offer the following comments.

Just by the study of a single scene of one date and that too purposively selected, the authors have ventured to generalize the findings to the entire Himalayas and estimate a dynamic process like forest degradation. At least two scenes chosen on a statistical basis, and at least of two dates, could provide a statistically valid estimate of forest degradation.

If the purpose was to compare estimates of the authors and FSI, it is imperative that definitions of vegetation classes, density classes and reference area are kept common. It seems that even the reference areas chosen are different, viz. the authors confining to their chosen scene and FSI, covering the entire district, making the comparison erroneous. This is obvious from the authors' estimates of forest cover in Almora and Pithoragarh districts as 72 and 71%, compared to FSI estimates of 48 and 36% respectively. The authors' estimates will seem too high even to a casual tourist travelling in the districts.

The analytical design for the study leaves much to be desired. As a consequence, the broad-leaved forests and herbaceous layers have not been well separated during the digital image interpretation process. Author needed to follow a classification tree, to achieve highest accuracy level in the forest and no-forest classes.

Finally, it would have been befitting to study all FSI State of Forest Reports (SFR) published after 1999, in addition to 1999, which the authors make a basis for comparison and criticism. SFR 2001 provides a detailed description of accuracy assessment in Annex II; and SFR 2003 provides forest area broken down into three classes, viz. Very dense, Moderately dense and Open, and a transition matrix showing the path of change.

1. Prabhakar, R. *et al.*, *Curr. Sci.*, 2006, **91**, 61–67.

K. D. SINGH

K-30 Hauz Khas Enclave,
New Delhi 110 016, India
e-mail: karndeo_singh@hotmail.com

Response:

D. Pandey and K. D. Singh address only the comparison of our results with those of the Forest Survey of India (FSI). It is worth mentioning that this was not the primary purpose of our article. Rather, the main aim was to present a method for ascertaining the extent of uncertainty in estimating how much of the forest area is degraded. We applied this method to a portion of the Himalayas and found, somewhat to our surprise, that the FSI's figures for proportion of forest area degraded, was well below the lower end of our 90% confidence intervals in two districts covered by our study. This fact, which we discovered in the course of our investigations, was naturally worth mentioning and we did so in the article.

In response to the comment that the image was taken at the wrong time of the year, we would like to point out the following: First, since our classification was supervised, meaning that the signatures in our IRS LISS-3 image were classified on the basis of their correspondence with ground surveys and visual inspection of a high-resolution Ikonos image, the time of year is irrelevant. It would be relevant only if we had used unsupervised classification or used signatures from a different image. Second, in any case, we assessed the accuracy of the classification using the high-resolution Ikonos image. So we know the range of error in the classification, and we adjusted for it in calculating the areas degraded. Indeed, this was one of the main parts of our article.

It is also stated that we overestimate forest degradation by including scrub area in the forest area. In the Central Himalayas, scrub is the final stage of forest degradation (with the exception of naturally occurring, high-altitude scrub which is negligible in quantitative terms). As mentioned in the article, we believe that the FSI has grossly underestimated the area under scrub. Thus the FSI naturally underestimates the proportion of what was originally forest and subsequently degraded. We stated in the article that the FSI's estimates for the area under scrub are unbelievably low. According to the FSI's State of Forest Report (SFR) 1999 (table 3.26f (http://www.envfor.nic.in/fsi/sfr99/chap3/up/uttar.html#fr), Almora District had a total geographical area of 5385 sq. km, of which only 21 sq. km was scrub. No one, who has been to Almora district could consider that such a low figure is possible. In fact, out of 62 districts in Uttar Pradesh listed in the table, FSI reports that 32 of them had 0 sq. km of-scrub! It is evident that the under-reporting of scrub was not confined to the hill districts.

Now, on the comment 'it appears that even grasses have been included in the forests …'. In fact, we have made it perfectly clear in our article that we have not included grasses in forest or scrub (table 3; p. 63).

It has been pointed out that we have not referred to the latest SFR. This is correct. We used the 1999 report because the reference period for that report included 1998, the year of our image. We should add, however, that using SFR 2003 does not change matters very much. The FSI has not reported district-level figures for area under scrub in SFR 2003 on its website. So we cannot make district-level comparisons. However, this report (available at http://www.fsiorg.net/fsi2003/index.asp) states that only 40,269 sq. km in India, about 1.2% of the total geographical area, is scrub. In contrast, the Ministry of Rural Development in its 2001–02 annual report (as quoted in IndiaStat.com) reported that about 639,000 sq. km or 19.5% of India's area was wasteland. There are other categories of wasteland, of course, but it is unlikely that so little of it would be scrub. In Uttaranchal, 320 sq. km, about 0.6% of the geographical area is reported by the FSI to be scrub. We find this hard to believe. It is probably the case that in India as a whole, as is certainly true in Uttarakhand, a considerable part of the scrub that exists was once forest that is now degraded. Under-counting of scrub will underestimate forest degradation.

With regard to the comment 'If the scrub is included in the degraded forest area, the percentage of the degraded forest would obviously be inflated', it seems to us to be a procedure that will result in defining forest degradation out of existence.

It has been correctly pointed out that in the top row of table 3 of our article, we compare our estimate of the per cent of area under forest or scrub in Pithoragarh (65–75) with that of the FSI (36), without taking into consideration the fact that we leave out about 22% of the area of the district since our image did not cover it. The northern part of this district, comprising 15% of its area, is under snow. So our estimate should be adjusted downwards. When we do this, we get an estimate of (52–58%), closer to the FSI's estimate, but still considerably higher. This is most likely because of FSI's underestimation of scrub.

R. PRABHAKAR

Ashoka Trust for Research in Ecology and the Environment,
No. 659, 5th 'A' Main, Hebbal,
Bangalore 560 024, India
e-mail: prabha@strandgenomics.com

Seismogenic significance of lineaments of the Indian subcontinent

Roy[1] has brought out seismogenic significance of certain 'lineaments' of the Indian subcontinent. Considering these lineaments broadly as tectonic corridors (or their parts), it appears that most of the intracontinental seismicity is concentrated along them[2], especially if these are affected by the Deccan trap (DT; or Reunion plume) activity. For example, Kutch rift (Allahbund, Anjar and Bhuj), Narmada–Son lineament (Jabalpur, Khandwa, Son and Khambat), Godavari graben (Bhadrachalam), etc.

In the context of 'lineaments', occurrence of two stable continental region earthquakes, viz. Koyna and Latur seems enigmatic at the first instance because their epicentres lie within the DT-covered basement, which is presumed to be the north-to-northwestward extension[3] of the Greater Dharwar Terrain (GDT). The term GDT has been used to imply that the Dharwarian shield is composed of more than one domain (e.g. Western and Eastern Dharwar cratons)[4–6]. Our study[7], as a matter of fact, has aimed at examining whether the combination of lineament and DT cover is applicable to the Latur and Koyna earthquake regions also.

Roy is correct when he suggests that 'our preposition does not hinge on any geological evidence'. But this is simply because in case of the DT-covered basement (thickness of cover varies from ~ 200 to 1500 m), it is extremely difficult to know the exact nature, structure and composition of the underlying basement only by geological means. In such a situation, the deep geophysical probings or drilling (which is prohibitively costly), can throw light on the nature of the basement matrix. Exactly this has been attempted in our study[7] where (a) the results of deep geophysical investigations, (b) spatial distribution of the magnetotelluric[8,9] (Sarma *et al.*, 1998, unpublished report) and deep seismic sounding[10–12] profiles, and (c) comparison of deep crustal structure beneath exposed and covered parts of the basement (or Dharwar craton) have been utilized. It allowed deciphering of spatial continuation of the deep-seated geotectonic features (or tectonic boundaries) of the Dharwarian terrain hidden under the DT cover.

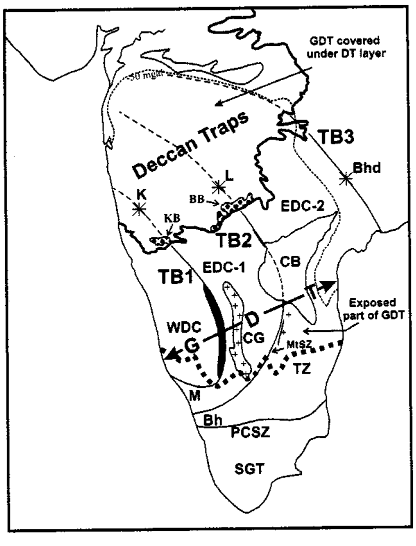

Figure 1. The Greater Dharwar Terrain (GDT) seems to be composed of different domains (WDC, EDC-1 and EDC-2), which appear to have accreted/sutured along the tectonic boundaries (TB1, TB2 and TB3). BB, Bhima basin; Bh, Bhavani shear zone; Bhd, Bhadrachalam; CB, Cuddapah basin; CG, Closepet granite; K, Koyna; KB, Kaladgi basin; L, Latur; M, Moyer shear zone; PCSZ, Palghat Cauvery shear zone; SGT, Southern granulite terrain and TZ, Transition zone.

The main finding – on the basis of magnetotelluric, deep seismic sounding and long wavelength gravity[13,14] and magnetic[15] studies – is that both Koyna and Latur earthquake epicentres also appear to lie within (or in close vicinity of) the northward extension of the interdomain accretionary corridors (e.g. boundary between Western and Eastern Dharwar cratons that seems to lie between Chitradurga schist belt and Closepet granite) of the GDT under the DT cover (Figure 1). Actually this inference strongly supports Roy's thesis that 'lineaments' play a major role in seismogenesis over the Indian subcontinent, because in case of Koyna[16] and Latur[17], the tectonic boundaries – TB1 and TB2 – seem to become activated lineaments. This is perhaps due to fluids released during the DT (or Reunion plume) activity and the two break-ups (at ~ 90 and 64 Ma)[18–21], which carved out the western margin of India.

We hope that the elaboration, as outlined above, would clarify the issue raised by Roy.

1. Roy, A. B., *Curr. Sci.*, 2006, **91**, 456–463.
2. Raval, U., *Proc. Indian Natl. Sci. Acad.*, 1999, **65**, 209–260.
3. Radhakrishna, B. P., *J. Geol. Soc. India*, 1989, **34**, 1–24.
4. Ramakrishnan, M., Viswanatha, M. N. and Swaminath, J., *J. Geol. Soc. India*, 1976, **17**, 97–111.
5. Radhakrishna, B. P. and Naqvi, S. M., *J. Geol.*, 1986, **94**, 145–166.