the high landrace probability zone. However, Kusur is in
the moderate probability zone; this is mainly because it is
located in the specified road buffer area and in identifying
landraces, remoteness was one of the major criteria.
The results were mainly based on the ranks and weights
that were given to classes and layers respectively. Multi-
criteria analysis was performed using different ranks and
weights. Results were cross-checked with the ground
knowledge.

The present study is limited to identifying the probabil-
listic zones for landrace cultivation based on the given
criteria. However, extensive field investigations, including
various socio-economic factors can reveal facts regarding
the landraces and their dependency on the forest ecosystem.

The application of space technology coupled with GIS
for identifying landrace zones has not been exploited by
researchers. Not much work has been done in India or
abroad in this regard. Tiny field sizes, similarity in spec-
tral nature of landraces and normal crops poses difficulty
in identifying landrace fields using space technology.
However, it is possible to delineate the possible landrace
zones using multiple criteria. These criteria are also useful
in separating the landraces from normal crops; how-
ever, the criteria may vary in different geological regions.
IRS LISS III, which has a spatial resolution of 23.5 m,
can be successfully used in delineating the probable land-
races zones. Conservation of landraces has gained signi-
ficant importance, mainly due to continuous loss of these
precious gene pools. Landrace zonation can aid in priori-
tizing the areas for conservation.


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A signal of increased vegetation activity of India from 1981 to 2001
observed using satellite-derived fraction of absorbed photosynthetically
active radiation

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An analysis of monthly fAPAR dataset derived from
NOAA–AVHRR data using an RT model by Mynden et
al.,1 covering the period from July 1981 to May 2001
over the Indian land mass was carried out. Monthly
twenty-year average fAPAR over India as well as
three latitudinal zones (8–16°N, 16–24°N, 24–36°N)
was studied for mean annual and seasonal (June–
October, November–May) trends. Results indicated
highest mean fAPAR averaged over the Indian land
mass in October (0.658) and lowest in June (0.342).
Significant positive trends of decadal increase of about
2.9 and 2% were observed in pre-peak (June–October;
P-I) and post-peak (November–May; P-II) seasons
respectively. The highest mean fAPAR was observed to be
0.80 for the central zone and 0.802 for the southern
zone in P-I and P-II seasons respectively. The trend in
fAPAR varied with the three latitudinal zones and was
higher for the southern zone (0.33% per year) over
the P-I season, while it was higher for the central zone
(0.18% per year) over the P-II season, in comparison
to the other two zones. In contrast, Ganganagar
district (Rajasthan), where irrigation-led increase in ag-
riculture activity has dominated during the past two
decades has shown significant decadal increase of 5.1
and 4.1% in P-I and P-II season respectively. The
results suggest an increase in vegetation activity as re-
lected in satellite-derived fAPAR over India during
the past two decades, however the spatial distribution
as well as the cause should be further investigated.

RECENT studies have indicated that the earth has become
greener owing to changes in global climate and/or anthrop-
ogenic activities.4–6. With the availability of satellite
data, especially during the last twenty years, several re-
searchers have found that plants have flourished in many
areas in the tropics, mid-latitudes and the far northern
forests because they received more sun, water, heat, car-

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bon dioxide (CO₂) or due to intensification of agriculture. Myreni et al.⁷ and Shabanov et al.⁸ have provided evidence for extended growth seasons and increased biospheric CO₂ absorption in the northern mid- and high-latitude areas (45 to 70°N) from satellite sensor-based data and atmospheric CO₂ concentrations, because of the marked warming in the spring time owing to an early disappearance of snow. Nemani et al.⁷ have investigated global vegetation responses to climate data and vegetation activity using satellite data coupled with models and found 6% increase in global net primary productivity (NPP) (3.4 Pg of carbon for 1982–99). This study described that the largest increase in NPP was in the Amazon forest, which cannot be explained solely by CO₂ fertilization. It further suggested that the increase in solar radiation, owing to mainly declining cloud cover in these predominantly radiation-limited forests, is the most likely explanation for increased NPP. For the northern mid-latitudes and high-latitudes, other studies⁵,⁶ suggest that multiple mechanisms (e.g. nitrogen deposition, CO₂ fertilization, forest regrowth and climatic changes) have prompted increases in NPP, whereas increases in the tropics have been primarily attributed to CO₂ fertilization and increased water availability. Since most of the studies are global in context and these have mostly found large increase in higher latitudes, the variation in the tropics and especially in countries like India which have more area under human-dominated agroecosystem where the total food production is increasing, needs more investigation.

The quantum and inter/intra-seasonal variability of NPP over India has not been adequately investigated. This is in the backdrop of continued increase in agricultural/crop productivity due to factors such as irrigation, fertilizer application and better crop management. Estimates of total NPP for India, made for the purpose of terrestrial carbon cycle assessment⁹, were 1.24 Pg Ca⁻¹ sec⁻¹ for 1980 and 1.32–1.59 Pg Ca⁻¹ for mid-eighties⁸; but a recent remote sensing-based study¹⁰ using with a C-fix model that uses a constant ε, indicated that the total NPP in India was 2.18 Pg Ca⁻¹. The agroecosystem C-cycle studies have also highlighted increase in crop NPP in India. The crop NPP was estimated to increase from 115 to 238 g Cm⁻²a⁻¹ between 1950 and 1985, using crop production to biomass conversion factors⁹. Several factors could give rise to NPP; for example, as discussed in a recent global study by Nemani et al.⁷, NPP increase could be due to favourable weather or higher plant activity, although both are interlinked.

Regional estimates of NPP are generally made using different approaches such as inversion of atmospheric CO₂ measurements, climate-driven models and remote sensing data-based models. Intercomparison amongst models of varying complexity ranging from simple Photosynthetic Efficiency Model (PEM) to complex physiological models, has given 40–80 Pg C as the global NPP estimate⁹. Monteith¹,¹¹ in a classical study, explained variability in NPP in the form of its three constituent factors, namely fractional absorbed PAR (fAPAR), incident PAR (IPAR) and efficiency (ε) of conversion of absorbed PAR to dry matter, i.e. NPP = IPAR × fAPAR × ε. This simple model is referred to as the PEM. While incident PAR or insolation is dependent on atmospheric turbidity, fAPAR which measures the proportion of available radiation in the photosynthetically active wavelengths (400–700 nm) that the vegetation canopy absorbs, is solely determined by green LAI, pigment concentration and leaf arrangement. ε has a complex dependence on a number of factors, including vegetation type, its stage and climate. The PEM framework is ideal for understanding the dependence of NPP on PAR, fAPAR and ε. Study on ε requires field measurements, while IPAR is either measured or estimated from model outputs or surrogate variables. fAPAR has a strong dependence on land cover/vegetation type and its seasonality and leaf area index are captured by remote sensing observations. The NDVI–fAPAR relationship has been studied using empirical models as well as RT model-based approaches¹.

In this communication, results from a study on inter-annual and intra-seasonal variation of fAPAR over India for a twenty-year period are presented. The fAPAR was derived from NOAA–AVHRR data using a physically based three-dimensional radiative transfer model of Myreni et al.⁷ considering six biome types for the globe. The dataset has a spatial resolution of 16 km x 16 km and the temporal coverage is monthly, spanning the period from July 1981 to May 2001.

We have explored fAPAR time series to infer the signal for increased vegetation growth in this study. The processing steps followed in this study are: (a) Extraction of sub-scene covering the Indian land mass (4°N-39°12’N, 65–100°E) from global fAPAR data. (b) Creation of a 239-image layer stack comprising monthly data over a twenty-year period (July 1981 to May 2001). The fAPAR data were in Sample Interrupted Goode projection with WGS-84 datum and the scaled data values ranged from 0 to 250, which were converted to actual fAPAR values by applying a conversion factor of 0.004. (c) Computation of pixel-wise (16 km x 16 km) monthly climatology of fAPAR for the India land mass (except islands) from 1981 to 2001. (d) Investigation of trends at annual and seasonal (June to October and November to May of next year) scales for three latitudinal zones over India (S: 8–16°N, C: 16–24°N and N: 24–32°N).

The average monthly fAPAR distribution over India for the period July 1981 to May 2001 is shown in Figure 1. Maximum fAPAR (large red patches) is observed in October and minimum in June, while between May and June reduction especially in the Northeast and the Western Ghats can be observed. These climatic fAPAR images synthesize the features associated with vegetation phenology, agricultural practice as well as rainfall patterns. High fAPAR in the Indo-Gangetic plain between January and
March due to agriculture (rabi season crops) and maximum fAPAR due to the SW monsoon in September–October in the eastern peninsula can be observed. High-altitude forest areas in the Northeast, the Western Ghats and Jharkhand–Orissa have high fAPAR, indicating forest green cover with extended duration of high fAPAR.

The mean monthly time series of fAPAR over India is given in Figure 2. The maximum average climatic fAPAR of 0.658 was observed in October and minimum of 0.342 in June, while the annual mean was 0.516. The CV of monthly fAPAR was maximum for June (75%) and minimum for October (44.7%). However, a large year-to-year variability in peak minimum as well a shape of the post-peak shoulder that signifies the variability in winter fAPAR can be observed. After a peak fAPAR in 1990, 1991 had a lower peak and a gradual increase in peak between 1991 and 1997 can be observed. From 1998 the peak values are low; lower peaks were observed in 1982, 1987–88 and 1990–91 and the shoulder can be observed as a separate peak in 2000. In order to analyse the variability in greater detail, mean fAPAR over three latitudinal zones (S, C and N) were computed. The temporal averaging period used was June to May and not the calendar year to (a) highlight the effect of SW monsoon on fAPAR and (b) make data compatible with the agricultural year. The averaged June–October (P-I, five-months) and November–May (P-II, seven-months) periods were considered to mainly cover kharif and rabi crop season respectively. This averaging would capture the rise in fAPAR (June–October) and subsequent decline (November–May).

The trends in seasonal averages of fAPAR during the past two decades for India are given in Figure 3a. The fAPAR during P-I was consistently higher than during P-II, and was in the range of 0.60 to 0.73. The average of P-I was 0.69 and of P-II was 0.65. A significant positive trend in fAPAR in both seasons was observed. The slopes were 0.0029 per year and 0.0020 per year for P-I and P-II respectively. Since the last four years (1998–2001) had lower fAPAR, trends for the smaller period of 1981–97 were also computed; these were significantly higher at 0.0044 per year for both seasons. The decline in mean seasonal fAPAR between 1998 and 2001 is associated with lower rainfall, which decreased from 119.56 cm in 1998 to 96.41 cm in 2001.

Analysis of fAPAR variability and change in three latitudinal zones (Figure 3b and c) showed that during the P-I season, the central zone had higher fAPAR (mean 0.76, range 0.70–0.80), the north zone had lowest fAPAR (mean 0.70, range 0.65–0.74), with an intermediate value for the south zone (mean 0.73 range 0.67–78). Although the northern zone included forests of the Northeast, inclusion of both warm desert of Rajasthan and cold desert of Jammu and Kashmir caused its mean fAPAR to be lowest amongst three zones. The three zones had a positive trend in P-I and decadal increase in mean was 0.033, 0.025 and 0.016 observed for southern, central and northern zones respectively. In the post-peak period P-II, the order of seasonal mean fAPAR was south (mean 0.77, range 0.73–0.80), central (mean 0.71, range 0.67–0.76) and north (mean 0.65, range 0.60–0.70). However, the trends in fAPAR although significant, were lower at 0.015, 0.018 and 0.011 per decade.
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Figure 3. Trends in seasonal-average fAPAR during 1981 to 2001 in India. a, Total Indian land mass. b, Zonal means over three latitudinal zones (N, C, S) in P-I season. c, Zonal means over three latitudinal zones (N, C, S) in P-II season. (N, Northern zone (8°–16°N); C, Central zone (16°–24°N); S, Southern zone (24°–32°N). P-I, Months from June to October of the same year; P-II, Months from November to May of the next year).

While the trends described above are for three large latitudinal bands, different regions and land-cover types could show different patterns. As a test case, for small area pattern, we studied seasonal fAPAR trend over Ganganagar district, Rajasthan. This district lies in an arid zone and has recently seen increased agricultural activity due to irrigation by Indira Gandhi Nahar Pariyojna. The observed decadal increase for this district is 5.1% in P-I and 4.1% in P-II, which is significantly higher than that for the all-India level.

The results point towards an increase of the order of 1–3% in a decade in aggregated fAPAR. The fAPAR trends are seen more in monsoon season where there is large inter-annual variability, although anomalies related to rainfall exist. During this period there has been a significant increase in foodgrain production (from 77.65 million tons (mt) in 1981 to 103.36 mt in 2001 for kharif season and 51.94 mt to 92.56 mt for rabi season). But from this analysis we have not separated trends for land cover, as at 16 m, a large proportion of mixed pixels would exist. However, it would be interesting to carry out detailed analysis of specific areas and land use/cover where change is happening. It may be pointed out that at a coarse resolution of 16 m, increased vegetation fraction in a pixel will also be picked up as high fAPAR signal. Even when the satellite data are properly calibrated, cloud-screened and atmospherically corrected, the inferred changes in fAPAR magnitude together with the spatial persistence and trend patterns shown must be interpreted cautiously. Several studies using long-term series of uniformly processed and calibrated NOAA–AVHRR data have been made for similar analysis.

Thus, an analysis of monthly fAPAR dataset derived from NOAA–AVHRR using an RT model by Myneni et al.1, covering twenty-year average and annual trends for India as well as three latitudinal zones was carried out, and it clearly brings out significant results. The fAPAR dataset when combined with information on incident PAR and efficiency of conversion for absorbed PAR (APAR) to dry matter (ε) can be used for estimating NPP. Amongst these two variables, radiation is measured at a few stations by IMD, and surrogate variables such as temperature difference or sunshine hours are generally used for its estimation. Recently, Kimothi et al.13 have demonstrated that insolation can be estimated from geostationary remote sensing data. ε requires field experiments for its estimation and reported values exist for a number of crops. Final NPP would be jointly determined by variation in all three factors (fAPAR, IPAR and ε). Results presented here clearly show that fAPAR captures vegetation activity and has shown a decadal increase of 2–3% at the all-India level, and seasonal variation in latitudinal bands have also been quantified. These results suggest that in contrast to increased radiation being an important factor to increased NPP in the Amazon,14 the vegetation activity increase itself over India could contribute to increased NPP. The exact quantification requires validated models, since climate and vegetation activity are interlinked. However, a study of Ganganagar district in Thar Desert where canal irrigation has increased gross sown area, has shown that the annual trends in increased vegetation activity are higher than those observed for the whole India. Converting fAPAR to NPP with accurately determined incident PAR and vegetation/weather-based ε is the next challenge.

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High molecular similarity among Indian isolates of Cucumber mosaic virus suggests a common origin

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Molecular similarity among Cucumber mosaic virus (CMV) isolates from *Amaranthus tricolor*, *Datura innoxia* and *Hyoscyamus muticus* was investigated by RT–PCR RFLP and sequence analysis of coat protein gene. RFLP analysis with *HindIII*, *SalI*, *ApaI* and *RsaI* indicated their placement into subgroup I of CMV. Sequence analysis and phylogenetic trees generated by nucleotide and amino acid sequence alignments placed Indian isolates into subgroup IB. They also showed a high molecular similarity among themselves and appeared as a distinct cluster within subgroup IB, indicating their common origin in relation to other members of the subgroup.

CUCUMBER mosaic virus (CMV), the type member of genus *Cucumovirus*, belongs to the family Bromoviridae. Particles of CMV encapsidate three linear plus-sense, single-stranded RNA species designated as RNA1, RNA2 and RNA3. The coat protein (CP) expressed through a subgenomic RNA (RNA4) encodes a 24 kDa protein. Various strains of CMV that differ in their biological, serological and physico-chemical properties have been isolated from all over the world. Based on serological data, nucleic acid hybridization, nucleic acid and/or protein sequence composition, RNAase protection assay and RT–PCR RFLP, they have been divided into two subgroups (I and II). On the basis of sequence data of several CMV strains reported all over the world, a further split of subgroup I into IA and IB has been proposed and Asian strains have been grouped under subgroup IB.

Characterization of various CMV strains has been reported from time to time in India. Biological, biochemical and serological differentiation of five strains of CMV was also studied. However, RT–PCR RFLP and sequence data-based molecular variability among Indian isolates of CMV have not been done so far, except a few preliminary reports. In the present communication, we report molecular similarity among CMV isolates from *Amaranthus tricolor*, *Datura innoxia* and *Hyoscyamus muticus*, which had been characterized earlier. CMV-Fny and CMV-P16 strains were also included for these studies as representatives of subgroup IA and IB respectively.

CMV-A17, CMV-Da18 and CMV-H19 isolates were maintained on their natural hosts and purified by following the virus purification protocol of Lot et al.20. RNA was extracted from each purified preparation through disrup-

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