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Identification of potential sites for *in situ* conservation of landraces associated with forest ecosystem – Geomatics approach

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Landraces may be defined as a locally adapted strain of a species bred through traditional methods of direct selection. There has been a continuous threat to these landraces due to outcrossing, migration of cultivators to the urban areas and replacement of high yielding varieties with traditional crops. Among many reasons to conserve forest ecosystem, landraces can be one of the important reasons, which focuses on protecting agro-biodiversity existing in the vicinity of forest ecosystem. One of the important observations was that, these landraces were present in proximity of forest areas where forest floor litter serves as source of manure. So it is implicit that without forests these crops cannot sustain. Forest floor litter, which is generally abundant in the study area, is gradually converted to humus, which during rainy seasons goes down-streams to agricultural areas. No chemical fertilizers are used for growing these crops. Since mapping of landraces using remote sensing data is difficult, an alternative

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approach is proposed for 'Mapping Potential Land Race Zone' rather than delineating agricultural patches. Land races are governed largely by terrain complexity and remoteness of villages. This information coupled with land use land cover map provides basis to perform multi criteria modeling, thus helping in identifying potential land race zones.

LANDRACES may be defined as a locally adapted strain of a species bred through traditional methods of direct selection[1]. These varieties are called farmer's varieties, as they are generally developed by the farmers and adopted to local environmental conditions. Farmers use landrace varieties for preparing specific recipes to satisfy their food requirements. These varieties are generally limited to isolated rural/tribal areas. Landraces have been grown in different parts of the globe including India. Ethiopia is a major world centre for genetic diversity of many important domesticated plant species[2]. Landraces are highly resistant to adverse environmental conditions. It was observed that in drought-prone areas of Ethiopia, mainly in Shewa and Wello regions, farmers still depend on the traditional system of agriculture[2]. In the Indian context, Maheshwari has studied various aspects of conservation of 'heirloom' varieties in agriculture ecosystem[3]. There has been a continuous threat to these landraces due to out-crossing, migration of tribes who grow these varieties to the urban areas in search of better livelihood and education for their children and also due to replacement of high yielding varieties with traditional crops. These species are vanishing continuously at an alarming rate. Once there were 30,000 varieties of rice in India, but it is believed that in another ten years it will be reduced to no more than 50 varieties[4]. Inventory about most of these species has not been made; so there is scarcity of scientific database of all these lost species. Efforts have been made to conserve the gene pool of the species under threat; but it was not practical. It was realized that the most practical way to conserve these gene pools is by continuously practising the agriculture of these varieties[3].

The information management of landraces is highly desirable in order to take effective management decisions. Geographical Information System (GIS) coupled with remote sensing (RS) can be a promising tool to provide up-to-date information about the spatial distribution of landraces in the form of maps. GIS can be used in ecogeographic surveying, field exploration and design management and monitoring of *in situ* reserves[5].

In the Indian context, considerable efforts have been made to characterize forest biodiversity using RS and GIS techniques[6,7], but not much stress has been given on landrace zoning using RS/GIS techniques. Often, landraces occur in the vicinity of forests and this is another good reason to conserve the ecosystem.

The geographical distribution of landraces is generally scanty; however, it is desirable to know the probable sites where these species can occur based on specific criteria. Different GIS tools, i.e. BIOCLIM[8], Domain[9] and Flora Map[10,11] have been developed to extrapolate information using climate data.

The present study attempts multi-criteria analysis technique for delineating landrace zones in the proposed Father Santa Pau Wildlife Sanctuary. This area is located between two major urban centres of Maharashtra, i.e. Mumbai and Pune. Yet the area is not much disturbed mainly due to its topography and inaccessibility. There are different traditional farmers residing in the area who grow landraces in small areas.

The proposed Father Santa Pau Wildlife Sanctuary, having an area of 122.96 km^2 is located near Khandala, District Pune (Figure 1). It is an important corridor between Bhimashankar and Koyana ranges of the Western Ghats. The sanctuary is located near Maval along Pune–Mumbai National Highway No. 4. The area is bestowed with forests, water bodies like Sahyadri Ganga, monuments like Father Santa Pau fort and other sites. It has been found in the survey that many species like *Achranthus coyenei*, *Vigna khandalensis*, *Gymnema khandalensis*, *Delliptera ghatica*, and *Canscora khandalensis* are endemic to the Lonavala and Khandala regions. From the biodiversity point of view also the area is rich. The total reserved forest of the area is 100.32 km^2. There are many places in the area that are important from tourism point of view. Some of the important places are Bhushi dam, Valvhan dam, Father Santa Pau point, Tigers leap, Kune point, Raiwad park, temple of goddess Ekveera, Aambvane, Bedsa leni, Duke's nose, Lohgad fort, Pavana dam, Shirota dam, Tungarli dam and Visapur fort.

From the geological point of view, the area is mainly composed of basaltic rocks, which is generally known as 'Deccan trap'. The area is mainly made up of lava flows. Rich deposits of alluvial soil are present on the banks of rivers and nalhas. Soil is less on the steep slopes with exposed rocks. Climate in the region is highly variable due to elevation differences. Rainy season is from June to

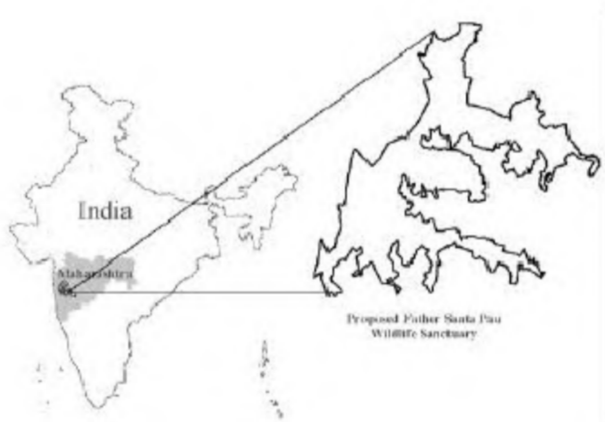

Figure 1. Map of the study area.

September, winter is from October to February and summer is from February to May. Generally, the temperature of the area varies between 7°C in December and 38°C in May. Mean annual rainfall in the study area is 6985 mm. It has been found in the survey that the area is rich in floral biodiversity. Due to high species diversity the area has high faunal diversity as well. Forty-two varieties of vertebrates, more than 250 varieties of birds, 40 varieties of reptiles, 9 varieties of aquatic animals, more than 150 varieties of butterflies have been reported in the area.

The major objectives of the study are: (i) landuse/landcover mapping using satellite data; (ii) to study the relationship between landuse/landcover and existence of landraces and (iii) delineation of potential landrace zones based on multi-criteria analysis in GIS.

As a part of Department of Space and Department of Biotechnology (DOS–DBT) sponsored project on 'Biodiversity Characterization at Landscape Level – Phase I b', inventory regarding landraces has been made in the study area. The widely grown landraces found are *Eleusine coracana* (Nachni), *Panicum miliaceum* (Varai) and *Panicum miliare* (Sava) which are the main source of food for the local population. Although most varieties could not be identified in the area, their presence is significant.

A format for landraces inventory was developed as shown below. The villages visited were Rajmachi and Kusur. Inventory was also made in Kamshet village which is outside the study area. However, it was useful in testing the hypothesis. These villages are spread far apart.

After making the inventory (Table 1), it was observed that the landraces are mostly grown in remote villages generally by tribes in the vicinity of forests and mostly on slopes. These varieties require less water and they are also disease-resistant. It was found that villagers grow these crops mostly to satisfy their food requirements and also to prepare specific traditional recipes out of them. The seeds of the old crop are preserved for sowing to the next crop. The main reasons for growing traditional crops are that they can adapt to local environmental conditions and also because they can be grown even if their is scarcity of water.

It was observed that these landraces are under threat as the traditional farmers who are cultivating these crops, are migrating to urban areas mainly in search of better education for their children.

One of the important observations is that landraces are often found cultivated at higher altitudes and in the vicinity of natural forests. Artificial fertilizers have not been used during cultivation of the crops. The obvious reason is that forest floor litter serves as a source of manure. Relationship of forest and landraces is so implicit that without forests these crops cannot exist. Forest floor litter, which is generally abundant in the study area, is gradually converted to humus, which during rainy seasons goes downstream to agricultural areas (Figure 2).

Upon interviewing old farmers, it was found that the crop varieties, which were grown in earlier times, are not grown currently. For example '*Khandva*' variety of wheat, which was grown 10 years back, and was supposed to be highly disease resistant is no more cultivated by farmers.

Identification of landraces using RS data is a difficult task, because of tiny field sizes and partly jhum cultivation practices, where agriculture is mixed with shrubs.

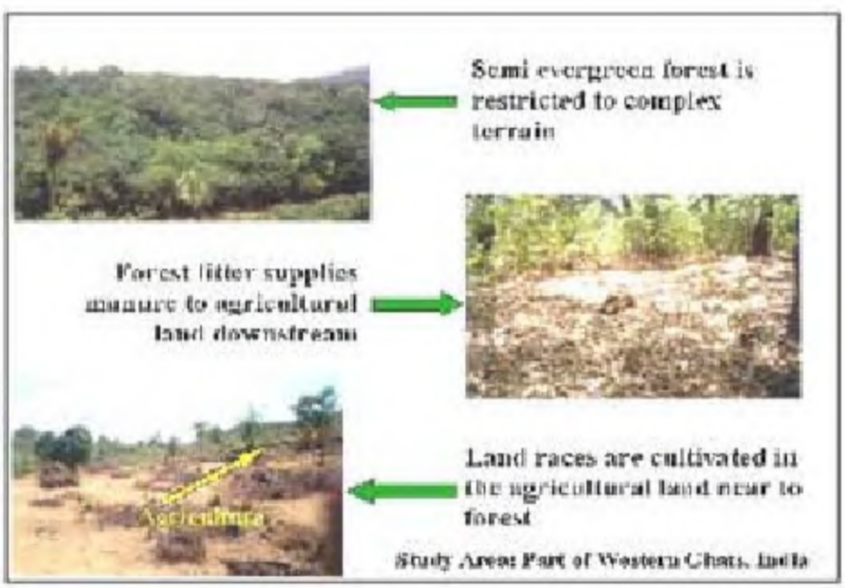

Figure 2. Study area.

Table 1. General landraces inventory

Form No.				
Location	Date		Remark	
SN	Name of the villager	Village	District	Occupation
1				
2				
Crops				
SN	Crop variety	Reason for choosing the crop	Origin of varieties	Seed source
1				
2				
Medicinal plants and their commercial exploitation				
Shifting cultivational cycle				
Species that are preserved during shifting cultivation				
Major land development activities				
Cattle				
SN	Cattle breed	Origin	Use	
1				
2				

Landraces are generally found in home gardens, which are small in size; so directly detecting them using satellite data is rather difficult. However, RS coupled with GIS can be effective in identifying zones of landraces based on specified criteria, which are directly related to landrace cultivation. Landraces are governed largely by complex terrain and remoteness of village. Using this information with precise landuse/landcover map provides a basis to perform multi criteria modelling, thus helping in the mapping of potential landrace zones.

For the present study, Indian Remote Sensing Satellite 1C (IRS-1C) data of February 2001 were used (Figure 3 *a*). Contours, road network, rail network and villages information was incorporated in GIS as thematic layers. The map prepared by Deputy Conservator of Forest Office, Pune Division was used to extract the boundary of the study area. All the topo-maps were registered to Lambert Conformal Conic (LCC) projection system. The parameters of 'Shivaji grid' were used for map registration. The 'Shivaji grid' is the standard reference system in LCC projection proposed for preparing spatial databases of Maharashtra State, suggested by Department of Space under NRIS programme. This standardization for Maharashtra offers a common framework for integration of spatial databases created at different organizations. The map prepared by Divisional Conservator of Forest Office, Pune Division was co-registered. Image-to-map registration was performed to register the satellite imagery. The study area was extracted from satellite imagery to perform further analysis.

RS and GIS inputs have been used to delineate the landrace zones. Thematic layers such as forest villages, roads, rails and contours were obtained from topo-maps. Digital elevation model (DEM) and slope were derived using GIS. RS image was classified to prepare land-use/land-cover map.

Details of the layers/maps and their significance for the project are as follows:

Village layer included villages that are either inside the study area or within the 100 m buffer from the study area boundary. Village buffer layer was generated for three levels, each of 500 m.

Only roads adjacent or inside the study area were considered for the present study, as other roads do not have much impact on the study area. Three level of buffers were generated, each at 500 m interval.

Only those rail tracks which were going inside the study area were considered. Three levels of buffer were generated along the track, each at 500 m interval.

The vegetation type map was prepared using hybrid approach of classification. This was important as there was mixing between classes. Hence in some areas of the image some classes were not spectrally separable. To avoid this, imagery was classified using unsupervized approach giving higher number of classes, i.e. 50. The benefit of this was that the spectral values were clubbed in small groups of classes and now only those classes were considered for further correction, which were spectrally not pure. Masks were created in the areas which were not classified correctly, and misclassified pixels coming under the mask were replaced with correct class value. Finally, all similar classes were merged together to obtain a single class.

Mainly, three forest classes, i.e. semi-evergreen, mixed moist deciduous and degraded forest are present in the study area. Other landuse classes are scrub, barren land and water (Figure 3 *b*).

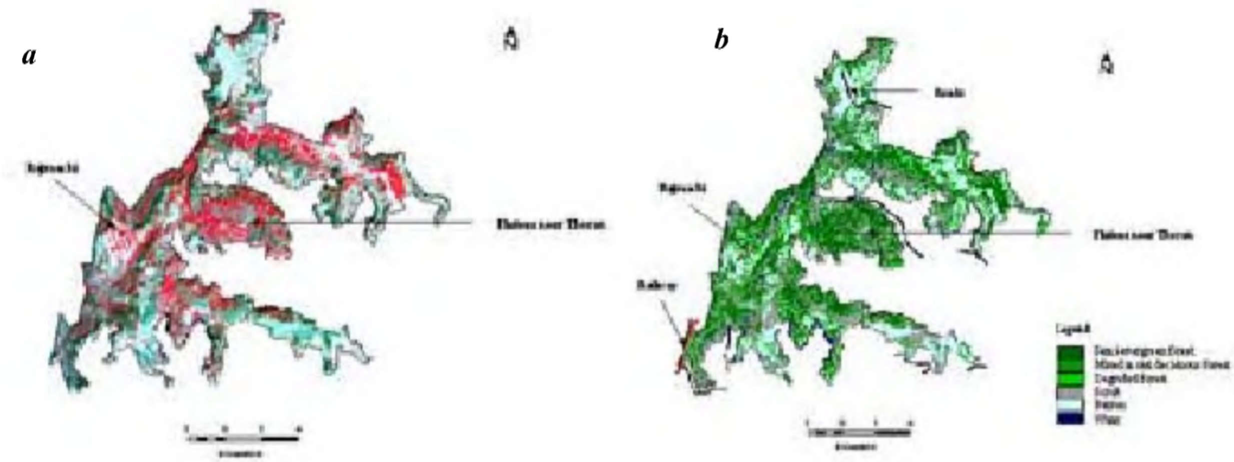

Figure 3. (***a***) False colour composite and (***b***) Vegetation type map (IRS-1D LISS III data).

Table 2. Ranking criterion for road buffer layer

Buffer level	Distance in m	Rank
1	0–500	1
2	500–1000	3
3	1000–1500	5

Table 3. Ranking criterion for village

Buffer level	Distance in m	Rank
1	0–500	5
2	500–1000	3
3	1000–1500	1

Table 4. Ranking criterion for rail buffer layer

Buffer level	Distance in m	Rank
1	0–500	1
2	500–1000	3
3	1000-1500	5

DEM generated using 15 m contour interval is shown in Figure 4 *a*. The darker areas represent lower elevations, whereas brighter areas represent higher elevations. The highest elevation in the study area is 3442 m. Elevation map is the basis for preparing the slope map, which is one of the parameters required to identify potential landrace zones.

The slope map was extracted from DEM (Figure 4 *b*). The darker areas represent lower slopes, whereas brighter areas represent higher slopes.

The multi-criteria model has been developed in order to delineate probable landrace zones. Different GIS and RS inputs, i.e. village, road, rail, landuse/lancover map, DEM and slope maps were taken into the model. The classes of each layer were given ranks based on their importance in the study. Each layer was given a weight based on relative importance of that layer in the study.

Each class of a particular thematic map is given particular rank and each thematic map is given particular weight. The criterion to assign rank and weight is as follows: ranks were given in the range of 1 to 5, with 1 being the least important and 5 being the most important parameter from landraces point of view. No values were given to the areas which were not considered for the study. Each thematic layer was assigned a weight ranging from 10 to 30 depending upon the bearing of that layer on landraces.

Roads have an impact on the existence of landraces. It has been observed during the survey that the major roads provide an opportunity to the villagers to have easy accessibility to seeds of high-yielding variety. The ranking criterion for the road buffer layer is given in Table 2.

In our survey and also in different reference studies, it has been observed that villages that are secluded, located inside the forest areas and not easily accessible are important from landraces point of view. Further, the landraces are generally grown in the home gardens. Hence there was a maximum probability of occurrence of landraces in the 500 m buffer from the secluded village. The ranking criteria for the village and rail buffer layer are given in Tables 3 and 4.

In the present study, forest areas are of significant importance. In the study area mainly three types of forest are found, i.e. semi-evergreen forest, moist deciduous forest and degraded forest. Semi-evergreen forests are located at high elevation and are also dense. The mulch collected on the forest floor moves downwards with rainwater, and

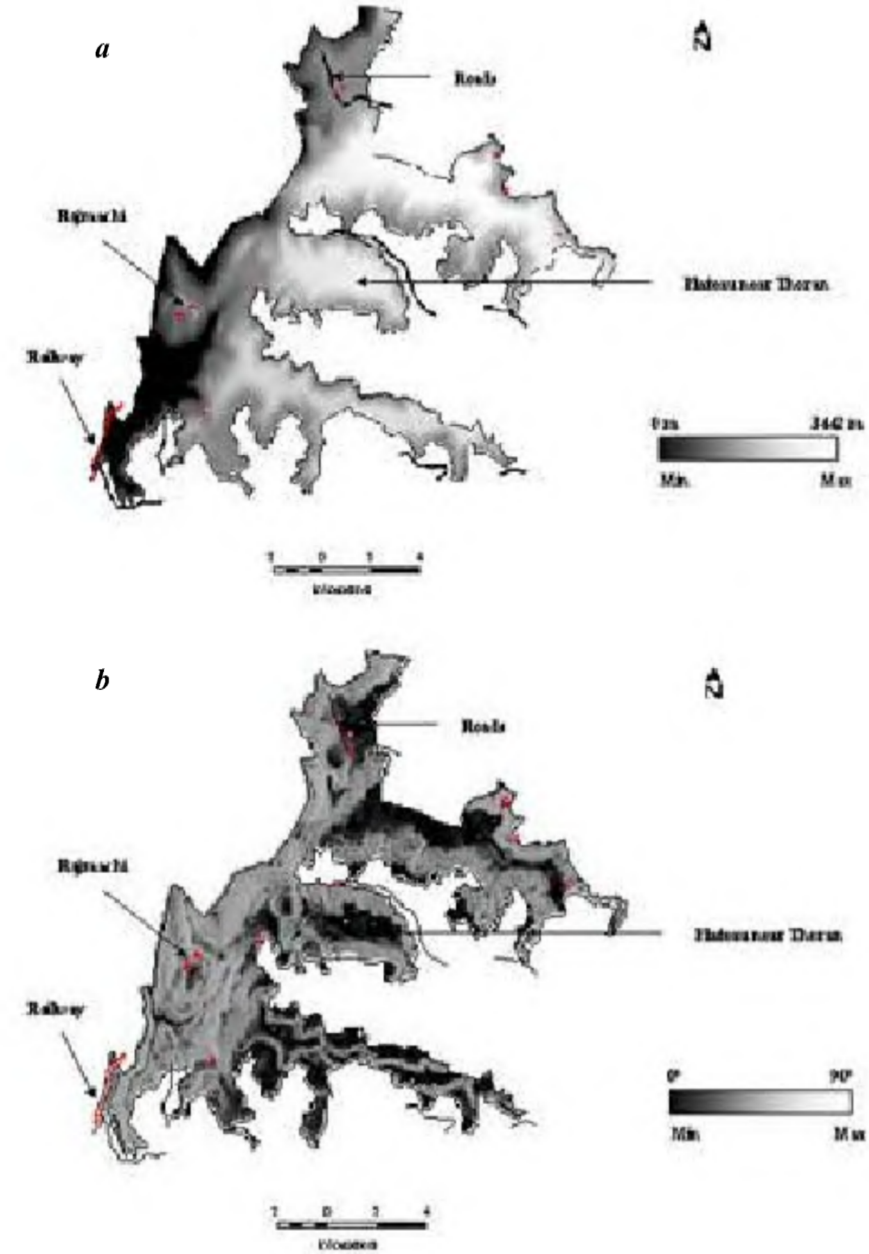

Figure 4. ***a***, Digital elevation model. ***b***, Slope map.

serves as manure for the landrace fields. Hence these forest types were given the highest weight. Moist deciduous forests are located at comparatively lower elevation and were given the next higher rank. Degraded forests were present on the foothills and were given the least rank. Other classes were not considered for the study and were not given any value.

The ranking criterion for landuse/landcover map is given in Table 5.

It has been observed that villages at high elevation in the study area are generally isolated and hence the ranks were directly proportion to the elevation. The ranking criterion for DEM is given in Table 6.

Slope is an important parameter. Generally, villages of the area are located on moderate to low sloppy areas. Very high slopes were not considered suitable for the present study. Hence moderate slopes were given the highest rank. The ranking criterion for slope map is given in Table 7.

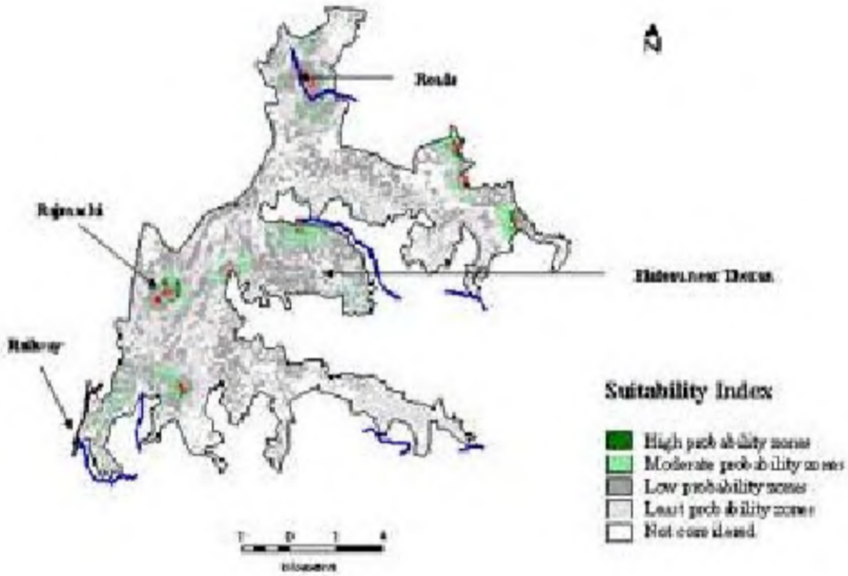

Figure 5. Map showing landrace zones.

Table 5. Ranking criterion for landuse/landcover map

Distance in m	Rank
Semi-evergreen forest	5
Moist deciduous forest	3
Degraded forest	1
Scrub	0
Barren land	0
Water	0

Table 6. Ranking criterion for DEM

Elevation in m	Rank
0–684	1
685–1367	2
1368–2051	3
2052–2736	4
2737–3442	5

Table 7. Ranking criterion for slope map

Slope in degree	Rank
0–30	1
30–60	5
60–90	3

Table 8. Relative weights of different input layers

Layers	Weight
Village buffer	30
Road buffer	10
Rail buffer	10
Landuse/landcover map	30
DEM	10
Slope	10

Different weights were given to the input layers based on their relative importance in the study. The classified and village layers were given the highest weights in the present study. These layers are of significant importance because mulch, which acts as manure for landraces comes mostly from the dense forest areas. Forests are responsible for survival of these landraces. Villages are also important for the existence of landraces, as generally the landraces are grown in home gardens or small fields surrounding these villages. Rest of the layers were given equal weightage.

Based on the above discussion, the relative weights given to different layers are given in Table 8.

After giving ranks and weights to all the layers, the multi-criteria model was executed in order to identify the most probable zones for landraces. The final map was density-sliced in five prominent classes, i.e. (i) High probability zones, (ii) Moderate probability zones, (iii) Low probability zones, (iv) Least probability zones and (v) Not considered (Figure 5). Areas around villages which are generally secluded, i.e. away from road, rail and located at higher elevation had high probability of landraces. Villages like Rajmachi, Thakurwadi, Satwawadi and Andrao were classified under the high probability zones. We have made a survey in Rajmachi and Kusur villages; according to the multicriteria model, Rajmachi is classified under 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 probabilistic 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 spectral 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; however, 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 landraces zones. Conservation of landraces has gained significant importance, mainly due to continuous loss of these precious gene pools. Landrace zonation can aid in prioritizing 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 Myneni *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 agriculture 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 reflected 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 anthropogenic activities[2–6]. With the availability of satellite data, especially during the last twenty years, several researchers 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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