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Impact of instream sand mining on habitat destruction or transformation using coupling models of HSI and MLR

Raj Kumar Bhattacharya[1] · Nilanjana Das Chatterjee[1] · Kousik Das[1]

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Abstract Several human activities like sand mining, dam construction have intensive effect on river ecosystem. Instream sand mining is one of them to hindrance on riverine biota. Hence, an attempt is made in this study to assess three tier habitat degradation or alteration caused by instream sand mining from channel bed to riparian and bank site in upper, middle and lower segments of Kangsabati River. Habitat Suitability Index (HSI) is applied to detect geo referenced ecological information on two different condition i.e. habitat suitability of two dominating species of *Koeleria macrantha* and *Cynodon dactylon* (pre mining) and degraded or altered habitat incorporated with mining responses (post mining). HSI prepared five different suitable class taken seven dominating variables i.e. river channel, sandchar, riparian zone, slope, elevation, dry and moist sand layer using multiple logistic regressions (MLR) under GIS platform. MLR denotes sandchar deposition, elevation as significant variables of *Koeleriamacrantha* dominance along the bank while moist sand layer, riparian zone signified on *Cynodondactylon* dominance across the riparian site. HSI indicates low-suitable class of *Koeleriamacrantha* and *Cynodondactylon* dominated in largest sand mining area as lower (82%, 86%), middle (58%, 89%) and upper segment (77%, 78%) whereas largest mining area under two dominant species reaches low-suitable class as lower (79%, 58%), middle (89%, 82%) and upper segment (92%, 70%) respectively. In spite of variables influence on species dominance, massive sand mining leads to destroy the habitat suitability. Therefore, in situ habitat suitability of dominant species either degraded or altered throughout the channel.

Keywords Instream sand mining · River ecosystem · Habitat degradation · Alteration · Habitat suitability

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✉ Raj Kumar Bhattacharya
rajgeovu10@gmail.com

Nilanjana Das Chatterjee
nilanjana_vu@mail.vidyasagar.ac.in

Kousik Das
kousikvugeo@gmail.com

[1] Department of Geography and Environment Management, Vidyasagar University, Midnapore, West Bengal 721101, India

1 Introduction

Human always tries to huge benefit from many blessing natural life support system like river ecosystem, landscape ecosystem etc. without considering there stability throughout the world since beginning of civilization [1, 2]. Sand mining is one of the leading human interventions on river system where several mining responses have direct or indirect effects on riverine biota in specific physical, chemical and biological environment under a river system [3–5]. Various onsite and offsite negative impacts rise up across the indiscriminate sand mining sites due to over sand extraction than natural replenishment [6]. According to ecological point of view, indiscriminate sand mining leads to physical habitat degradation and food webs deterioration through the inverse change of channel forms [7]. As a result, benthic organisms especially fish communit; polychatae; Crustacea; Mollusca are intensively declined whereas organism of aquatic ecosystem faces habitat alteration due to the absence of food and changes of sediment characteristics [8].

Plant species of river ecosystem are situated in three tier habitat system i.e. shaded riverine aquatic habitat (interface between river and adjacent riparian habitats), riparian habitat (transition site between river bed and bank) and riverbank habitat (outer margin of riparian site) [2, 9]. Most of the shaded riverine aquatic habitat concentrated in wet mining pit which generated over extraction of sand from river bed extended below the thalweg line or under the water table. Riparian and river bank habitat situated across the channel bed to flood plain site. Sand mining helps to habitat alteration systems from shaded riverine aquatic to bank site, which resulted in habitat quality degradation as well as biodiversity loss [10–12]. Therefore, three tier habitat (TTH) alteration and degradation of instream biota becomes larger in mining sites than sandchar sites.

Habitat suitable index (HSI) plays vital role to quantify this problem as well as to find species adaptation, habitat degradation, fragmentation, and habitat loss and migration [13, 14]. This model predicts the relationship between the spatial distribution of organisms and habitats whereas this model guides the conservation or management of threatened species [15, 16]. Remote sensing and GIS tool are applied to determine the habitat preference of several in situ species obtaining spatial information [17–19]. Contrastingly, land suitability of endangered species is determined through the integrated of several spatial-non spatial habitat factors [20–23]. Since 1980, Indian researchers were widely applied integrated habitat suitability model using several thematic layers under GIS platform like Mountain Goat in Rajaji National park, Great Indian Bustard and Lion in desert National park were predicted by HSI using LANDSAT-TM, IRS ID LISS III [24, 25].

Multiple logistic regression (MLR) is applied for further improvement in H.S.I model as well as predict suitable habitat sites incorporate with habitat related variables. All the dichotomous dependent variables were categorized in presence-absence data to formalizing the establish relationship between the environmental condition and species habitat requirements. MLR has wide implication for the detection of HSI under GIS techniques using integrated thematic layers. Relative operating characteristic (ROC) is used for validation of predicted species distribution under insufficient data whereas area under curve (AUC) helps to consider effective dominant factors for MLR model performance following every threshold probability value where easily access target species [16, 18, 26]. Several researchers were used MLR to prepared habitat suitability class of various wild like invasive ragweed [27]; *Tamarix* spp. [28] as well as monitoring of spatio-temporal grazing behavior of livestock animal like goat, sheep in USA [29]. In India, MLR is used to develop of habitat suitability i.e. muntjac and tiger in Chandori national park [30, 31], muntjac and goral in Central Himalayas [32] and striped hyena in Gir national park [33].

In Kangsabati river, *Koeleriamacrantha* (June) is dominated species on dry finer sand along the bank; *Cynodondactylon* (Durva grass) which is dominating plant species on moist sand or sand char and water weeds or mosquito fern or *Najasgraminea* (rectified water nymph) dominating aquatic species submerged on pit near the channel [34]. Sand mining has intensive effect on river biota either habitat alteration or habitat degradation from channel bed to bank is found in Kangsabati River. The relationship between sand mining and habitat degradation detect by the applying of HSI, which is determined adverse effects of instream sand mining on the river ecology along the Kangsabati River through the integration of thematic layers. Finally, HSI prepared habitat suitability map using multiple logistic regressions (MLR) on GIS platform taking dominating layers i.e. slope, elevation, dry sand, moist sand, channel, riparian zone and sand char following previous studies [35–37]. For this, we have prepared georeferenced ecological information on suitable habitats using ROC. The aim of this paper is to identify spatial distribution of habitat suitability of *Cynodondactylon* (Durva grass) and *Koeleriamacrantha* (June) as well assess the role of dominant parameters on suitability in three different mining segments as upper (Lalgarh), middle (Mohanpur) and lower (Kapastikri) in the Kangsabati River. Moreover, there has tried to establish the three tier habitat alteration or degradation from riparian to river bank caused by sand mining during pre-mining and post-mining.

2 Study area

Kangsabati is a non-perennial river originates in the uplands of Chhotanagpur plateau in Jharkhand, India and enters at Jhaldia in Purulia district and passing through Bankura, Paschim and Purba Medinipur districts of West Bengal. The study area covers Mukutmonipur dam to Chouka near Rajnagar segment of Kangsabati river basin (Fig. 1). Geological structure in Kangsabati channel is constituted by mainly two stratigraphic units (80%) i.e. Mica schist occasionally Garnitiferous and Oxidized sand, silt and clay with in situ caliche groups [38]. Average rainfall in this basin varies from 1500 to 1000 mm. The undulating hummocky plain land and plateau proper of upper segment has low average rainfall as 1080 mm whereas mean annual rainfall in middle and lower segments is more than 1500 mm as high rainfall zone [39]. Floristic province along the Kangsabati riverside has three tier habitat systems i.e. Shaded riverine aquatic, riparian

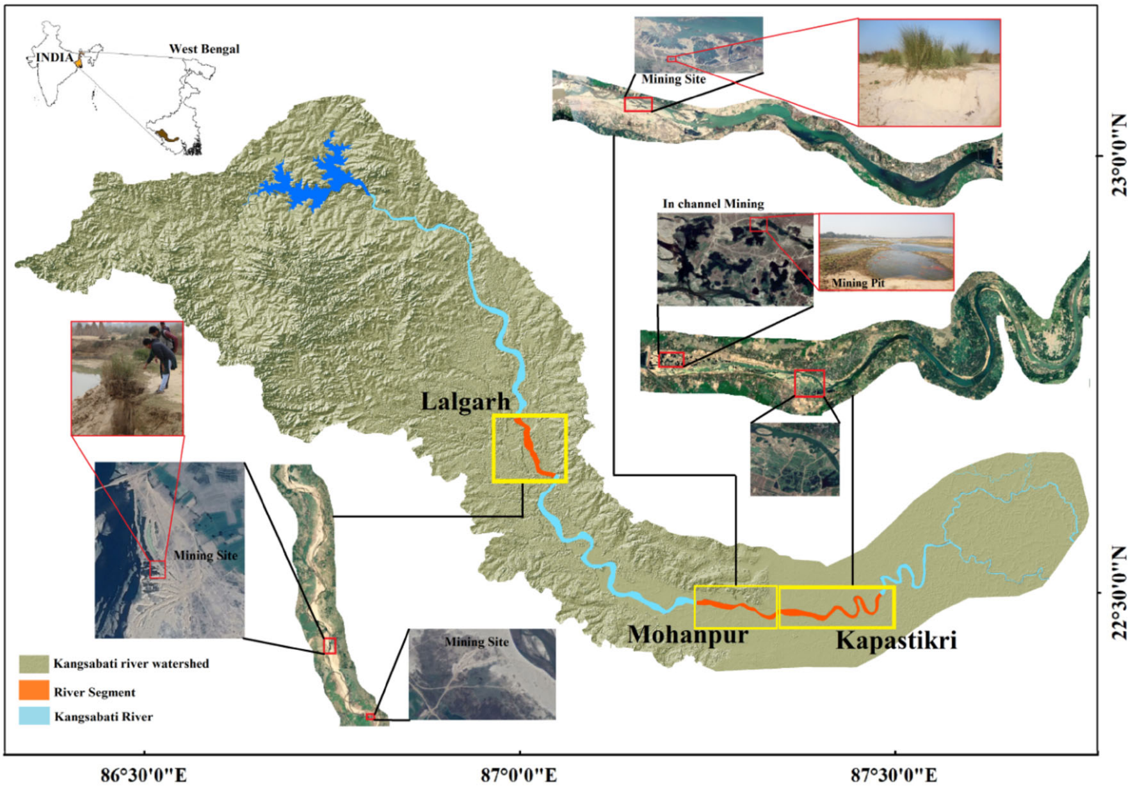

Fig. 1 Study area

and river bank sites. Several floating or submerged micro plant species such as *Egeria* spp. (water weeds), Mosquito fern, Najas graminea (Rectified water nymph), *Marsileaminuta* (Susni sak), *Potamogetonnodosus* (Kalay pata), *Vallisneriaspiralis* (Pata-jhangi) colonized on sandy channel bed while *Cynodondactylon* (Durva grass), *Mikania micrantha* (Banlanga), *Ludwigia perennis* (Raban lata) live in riparian site with the presence of moist sand char and clay layer (Figs. 2, 3, 4). Dry sand and rocky out crop leads to grow suitable habitat for *Koeleriamacrantha* (June), *Vetiveriazizanioides* (Kash), *Solanumnigrum* (Kanta begun) across the river bank (Fig. 5). On the other hand, massive instream and floodplain sand mining sites were established after the construction of Mukutmonipur dam (1958). Maximum extraction of sand concentrated in Lalgarh segment (75,058.03 m ton), Mohanpur segment (313,617.7 m ton) and Kapastikri segment (161,308.9 m ton) along the upper, middle and lower course (District Land & Land Reforms office of Paschim Midnapore and Bankura, WB 2002–2014). As a result, flow alteration or reduction has been occurrence by anthropogenic interventions and climatic change in the entire channel along the Kangsabati River [40]. Spatial distribution and species composition of plant species are substantial changes through water level fluctuation caused by dam construction [41]. Therefore, this paper an attempt has been made to document course wise effects of instream sand mining on three tier habitat alteration and degradation of river biota in upper segment (Lalgarh); middle segment (Mohanpur) and lower segment (Kapastikri) respectively.

3 Materials and methods

3.1 Geo-spatial data sets

In this study, different data sets have been used to extract dominant parameters on habitat suitability following respective researcher's i.e. dry sand and sandchar; riparian zone; channel; slope and elevation and moist sand including clay layer in Table 1. These are (1) ASTER DEM (at 30 m resolution) used for extraction of channel slope and elevation (2) Survey of India (SOI) topographic sheet (73N/7, 8, 9, 10, 11, 12; J/9, 12, 15; I/7, 8, 10 of 1:50,000) used for rectification of channel slope and elevation executed by ASTER DEM (3) high-resolution Google image (12.02.2016) used to run the MLR as well as preparing of land cover map i.e. channel, dry sand, moist sand, riparian, sandchar (4) LANDSAT TM with 30 m pixel cell size (dated on 10.01.2016) used for rectified of land covers (5) sand mining data in three mining segments of DL and LRO, Paschim Midnapore and Bankura (2002–2014). Field

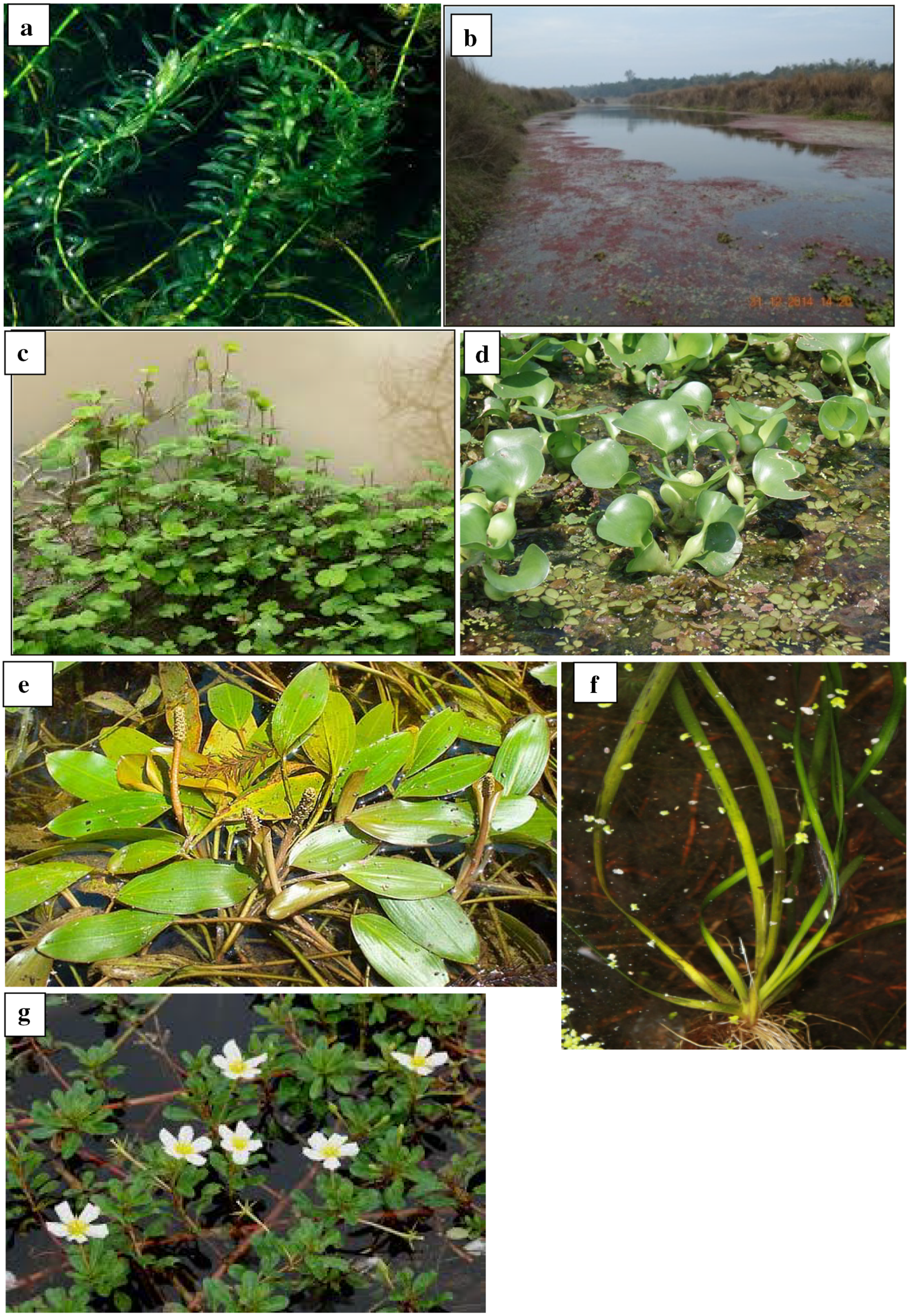

Fig. 2 Aquatic plant species in mining pits in Mohanpur, Kapastikri segments and Lalgarh segment, **a** *Egeria* spp. (water weeds), **b** *Mosquito fern*, **c** *Marsilea minuta* (Susni sak), **d** *Eichornia crassips* (kachuri pana), **e** *Potamogeton Nodosus* (Kalay pata), **f** *Vallisneria Spiralis* (Pata-jhangi), **g** *Ludwigia Adscendens* (Keshradam)

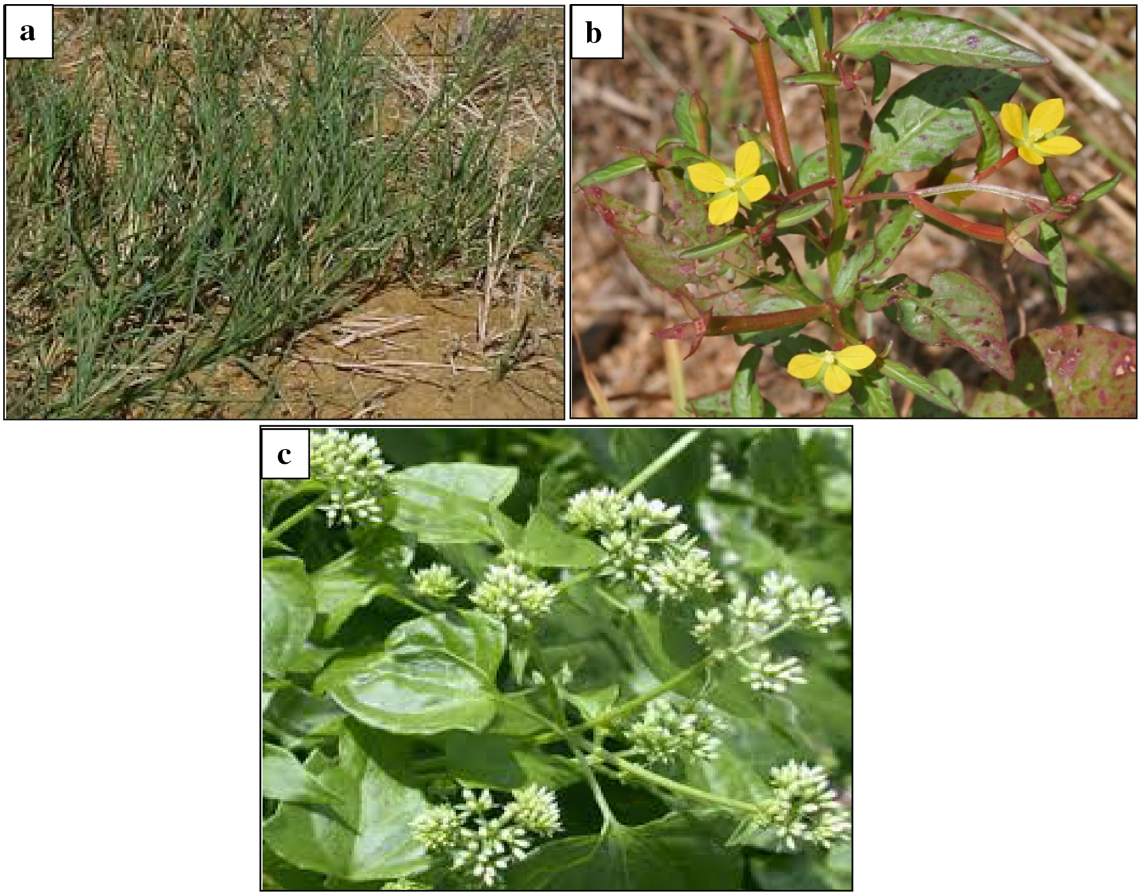

Fig. 3 Dominant plant species along the riparian site, **a** *Cynodon dactylon* (Durva grass), **b** *Mikania micrantha* (Banlanga), **c** *Ludwigia perennis* (Raban lata)

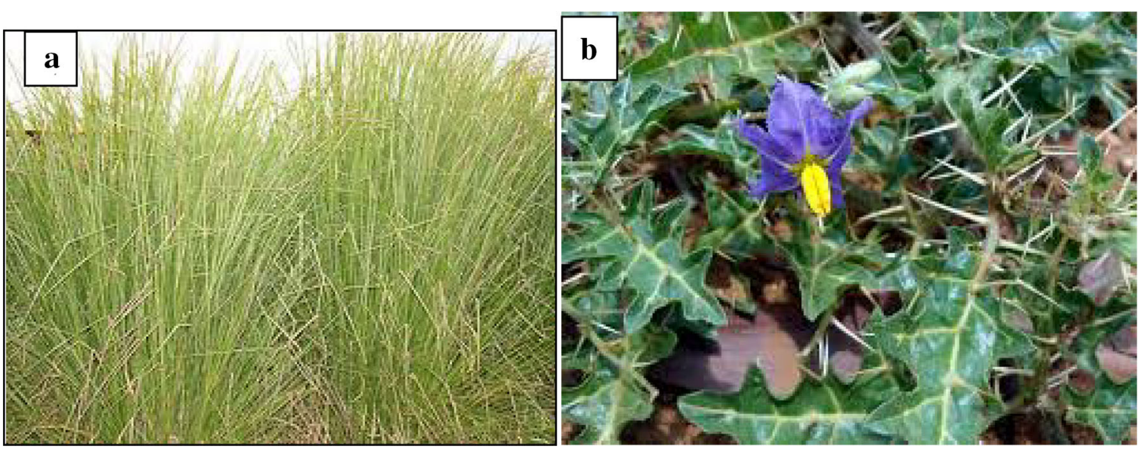

Fig. 4 Dominant plant species along the river bank, **a** *Koeleria macrantha* (June grass), **b** *Solanum nigrum* (Kanta begun)

survey was conducted to obtain the primary data of habitant characters of *Koeleriamacrantha*, *Cynodondactylon* and aquatic plant species like *Egeria* spp. (water weeds), Mosquito fern, *Najasgraminea* (Rectified water nymph), *Marsileaminuta* (Susni sak), *Potamogetonnodosus* (Kalay pata), *Vallisneriaspiralis* (Pata-jhangi) from three segments.

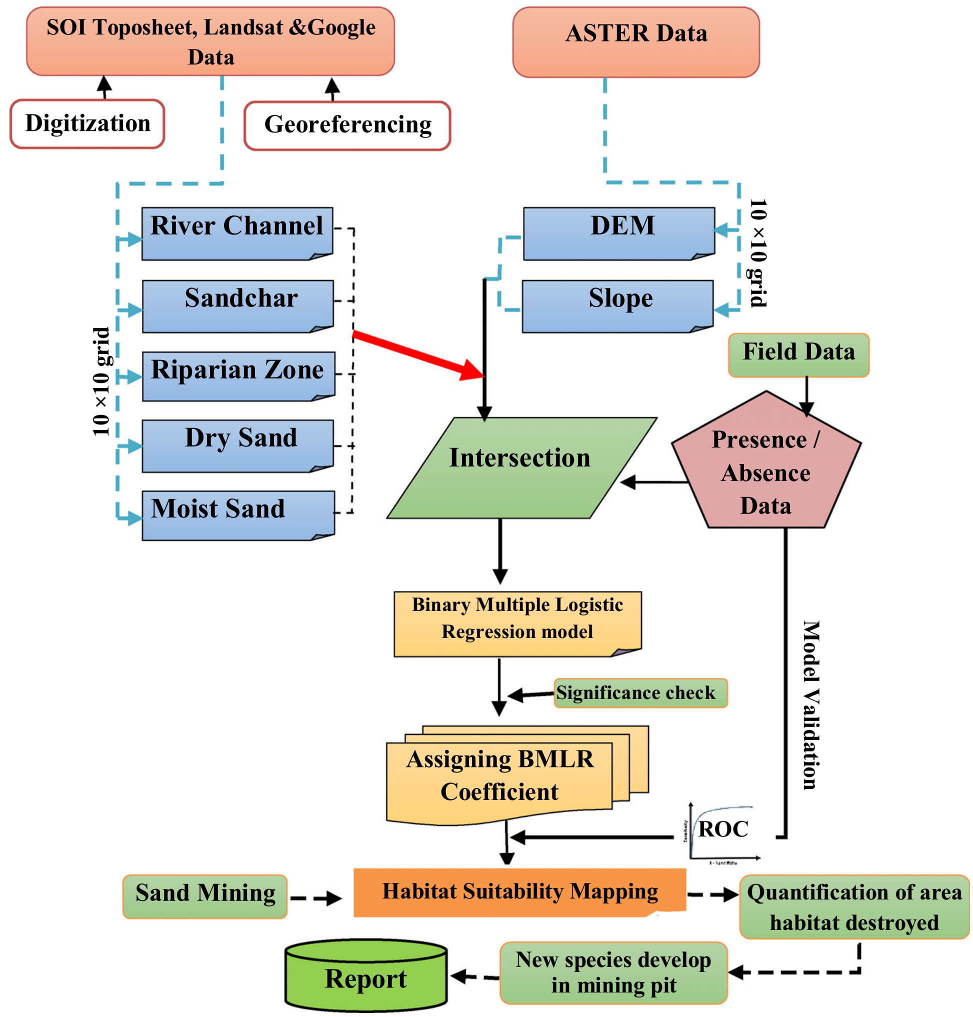

Fig. 5 Flowchart of Habitat Suitability Index Model assigned by binary multiple logistic regressions is edited as adding a arrow from estimated parameters to intersection (red arrows). (Color figure online)

Table 1 Data source of seven geo-spatial dominant parameters

Variables	Data source	Layer format and range	References
Moist sand	Google image, LANDSAT TM	Raster format; 0–1	[4, 9]
Dry sand	Google image, LANDSAT TM	Raster format; 0–1	[37]
Riparian	Google image, LANDSAT TM	Raster format; 0–1	[14, 37]
Sandchar	Google image, LANDSAT TM	Raster format; 0–1	[37]
Channel	Google image, LANDSAT TM	Raster format; 0–1	[35, 36]
Slope	ASTER DEM, SOI Toposheet	Raster format; 0°–21°	[35, 37]
Elevation	ASTER DEM, SOI Toposheet	Raster format; 87–0 m	[35, 37]

3.2 Estimation of habitat suitability parameters incorporate with mining intensity

Seven different dominate parameters are used to assess their significant role on habitat suitability of *Cynodondactylon* (Durva grass) and *Koeleriamacrantha* (June) before mining and then assess degradation or alteration of habitat caused by mining effect on them.

3.2.1 Channel

Perennial or non perennial channel plays vital role to control the species dominance from floodplain to channel bed [36, 37]. In this case, Kangsabati River falls under non perennial type but water level fluctuation continuously reduces after Mukutmonipur dam construction (1958). Therefore, spatial distribution and species composition from floodplain to aquatic plant species were substantial changes throughout the channel. On the contrary, massive instream and floodplain sand mining generated active mining pit floating on water, which leads to sustain shaded riverine aquatic habitat [10, 40, 41]. Water level governance leads role in assign the channel influence either 1 (presence of water) or 0 (absence water).

3.2.2 Sandchar

Dry sand or sandchar means accumulation of denotes stability condition of the segment if there is sediment concentration greater than removal of sand estimated by sediment budget. It is considered as stable species growth and dominance are positively related to sand deposition while species diversity declines in mining sites [39]. The relationship between species dominance and sand accumulation is assigned by presence or absence test. Stable or species dominance sandchar assigned with presence or 1 whereas unstable or species decline sandchar caused by mining assigned as absence or 0.

3.2.3 Dry and moist sand

Habitat suitability depends on the compactness of sandchar but species diversity in three tier habitat based on moisture availability of sand as also an important factor. Generally moist sand or exposed clay layer leads to growth of *Cynodondactylon* colony while dry sand sustain *Koeleriamacrantha* colony [14, 39]. But the extreme level of dry and wet situation in sandchar degraded the habitat. Habitat suitability in moist and dry sand falls under the presence class include 1 while degradation of habitat in very dry and wet sand belongs with absence class include 0 values.

3.2.4 Riparian zone

Riparian site is an intermediate zone between channel bed and bank margin [2, 41]. Three tier habitats depend on the presence of riparian site but mining activities degraded this zone. It also increased channel incision along both side. Riparian zone in upper segment mainly composed with rocky out crop but middle and lower segment covers with wet or moisture sand and clay layer. Resistant rocks represent habitat unsuitable class along the gravel bed channel [42]. TTH cannot grow successively due to unavailability of water in rock strata. On the contrary, the presence of rocky outcrop in upper segment is assigned by 1 and absence class denotes 0. In middle and lower segment, same assigning process like dry and moist sand is applied to measure the influence of riparian site.

3.2.5 Slope and elevation

Habitat suitability class intensively depends on slope variability across the channel cross profile and thalweg elevation gradually declined along with the channel bed which is influenced on habitat alteration and fragmentation. Channel erosion and deposition process mainly depend on bank slope and bed elevation in the study area [39, 40]. Both factors are assigned following the slope inclination ratio that means high class refers to 1 and low class with 0. All the upper segments fall under higher value whereas lower segments associated in a lower value.

3.3 Apply of Multiple Logistic Regressions (MLR) on probable prediction of mining effect

HSI results are validated and enhanced worldwide by the application of Multiple Logistic Regressions (MLR) statistic technique to predict outcomes of habitat suitability of selected plant species in form of a model. A model procedure based on two variables i.e. dichotomous dependent and continuous independent variables. Independent variable includes the surrounding habitat condition and dependent variables include species appearance. Habitat potentiality means quantifying the formal relationship between surrounding environmental condition and species habitat requirements with the application of MLA [26, 27, 43]. TTH alteration process or habitat degradation caused by sand mining is determined by the application of 'Boolean' rules in presence and absence class of all input layers whereas MLR statistical technique is applied to the assessment of suitable index through the integration of dependent or dichotomy and independents or continuous variables with multiple regression analysis during pre-mining phase. Integration probability is computed by computer software following the Eq. (1).

$$In(ODDS) = \left(\frac{\acute{Y}}{1-\acute{Y}}\right) = a + bx \tag{1}$$

where most of the event predicted probability code situated with 1 (presence) than 0 (absence), represent in $\acute{Y}$ whereas others decision oriented predicted probability denote $1-\acute{Y}$ and predicted variable denotes x.

3.4 Habitat suitability mapping

Finally, HSI is prepared with the application of Arc Map10.2 software whereas dominant parameters were overlaid through ASTER DEM and Google open image during pre and post mining. Validation of model result is done by BMLR using ROC in SPSS-19. This model detect the habitat suitability of several species while geospatial technology leads to make this model as an efficient and low-cost methods used by Remote sensing, GIS and Global Positioning System (GPS) [43]. Those are incorporated with high or low interpolation class following presence or absence observation. Input thematic favorable layers are co-registered with sub-pixel accuracy assessment (10 m × 10 m) and then this model run up with the following of flow chart in Fig. 5. All input independent variables were further analyzed for detection of signifies role on habitat suitability of *Koeleriamacrantha* and *Cynodondactylon* through raster themes transfer for derivation of regression coefficient from MLR under GIS domain.

3.5 Validation test

Habitat suitability model of two species i.e. *Koeleriamacrantha*, *Cynodondactylon* further fitting and relatively strong with the field data has been detected by obtaining the values of Model Chi^2 test (LR), − 2 log likelihood Model and Nagelkerke's pseudo-R^2. All input independent variables of habitat suitability were signified during pre-mining, obtains a regression coefficient of Chi-square value under the Wald test.

Receiver operating characteristic or ROC curve is applied to validate the model and signifies the relationship between habitat alteration or degradation and mining intensity during post mining. ROC curve is generated by all sensitive values plotting in Y axis and equivalent values of all sensitive threshold values in X axis (1-specificity). Overall accuracy in a single threshold value of each species is determined by important areal index or area under the curve (AUC) in ROC. The range of AUC values indicates accuracy level of predicting power in each species suitability if the value lies 0.5 denotes that the model has no predicting power whereas the range of values between 0.7 and 0.8 indicates that prediction of the model has successfully acceptable [26, 43].

4 Results

4.1 Habitat suitable parameters

Habitat parameters play vital role to run up the coupling models i.e. MLR and HSI through the transferring of all independent variables into raster format following presence and absence result. In channel, maximum presence area of flowing water concentrated near *Koeleriamacrantha* and *Cynodondactylon* in Kapastikri (2.74 km^2) and minimum presence near only *Koeleria macrantha* dominance in Mohanpur segment (1.57 km^2) whereas presence area near selected species dominance is 1.58 km^2 in Lalgarh (Fig. 6a–c). Maximum dry sand and sandchar presence area near dominant species are observed along the braid channel in Lalgarh (2.77 km^2) whereas dry sandchar deposited along the channel bed in Mohanpur (0.90 km^2) and Kapastikri (1.01 km^2). High concentration of moist sand observed only on Cynodon dactylon dominance in Kapastikri segment (2.75 km^2) and lowest concentration observed in Lalgarh (0.84 km^2) and Mohanpur segment (0.09 km^2). In riparian site, most of the presence area belongs with maximum sand mining sites observed in Kapastikri (9.94 km^2) whereas riparian site belongs near left bank covering with 1.87 km^2 near only Cynodon dactylon dominance in Lalgarh segment but, Mohanpur segment where riparian site belongs both bank site covering with 3.23 km^2. Slope ranges of very steep to low in three different segments like Lalgarh (0.064°–21°), Mohanpur (0°–16°) and Kapastikri (0°–15°). Elevation gradually reduces from Lalgarh (87.87–15.24 m) to Mohanpur (45–14 m) and Kapastikri (43–12 m). It is point that spatial distribution of dominant variables varies from one segment to another segment meanwhile their significance role become changes.

4.2 Logistic regression analysis of GIS data layers to derive coefficient value

Habitat suitable map of two plant species is generated from coefficient regression values by weight assigning of seven input thematic variables using MLR. On the other hand, predicted probability map produced from log-odds image by transfer of estimated log values in corporate with raster layers under GIS platform. Log transformation process leads to weighted of lower predicted values as well as extended of higher predicted values under the classified accuracy where positive cut-off value is 0.5. Based on cut off value, suitable map is classified into two types i.e. one is not suitable within the value of below 0.5 and other type is suitable site that means above 0.5 values. Moreover, significance of all input parameters are determined by beta coefficient (ß) either positive or negative relationship with habitat suitability in Wald test using MLR technique. The derivation process of beta coefficient (ß) value obtained from two plant species in three segments following as Eq. (2).

$$1/(1+\mathrm{EXP}(-(\mathrm{Constant}(\beta\,\mathrm{coeff}))+\mathrm{Moist\ sand}(\beta\,\mathrm{coeff}) \\ +\mathrm{Dry\ sand}(\beta\,\mathrm{coeff})+\mathrm{slope}(\beta\,\mathrm{coeff})+\mathrm{Sandchar}(\beta\,\mathrm{coeff}) \\ +\mathrm{Riparian}(\beta\,\mathrm{coeff})+\mathrm{Channel}(\beta\,\mathrm{coeff})+\mathrm{Elevation}(\beta\,\mathrm{coeff}))) \quad (2)$$

In Lalgarh segment, MLR result shows that dry sand, riparian zone, channel, slope and elevation significantly influenced on habitat suitability of *Cynodondactylon* along the riparian site whereas dry sand, sandchar, channel,

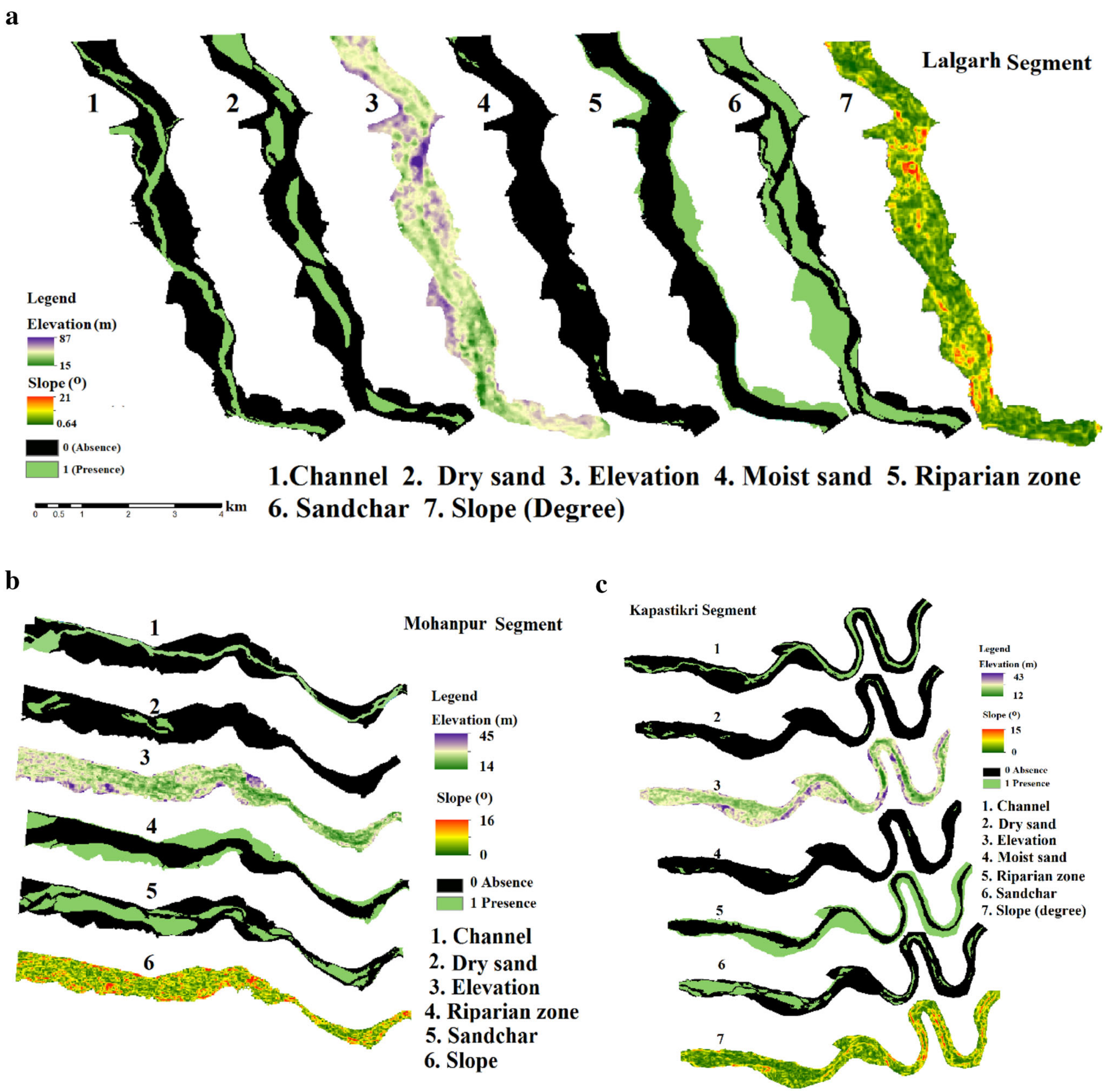

Fig. 6 Significant variables in different segment of Kangsabati River, **a** Lalgarh, **b** Mohanpur, **c** Kapastikri

elevation are significant variables on suitability of *Koeleriamacrantha* along the bank site in Table 2. In Mohanpur segment, riparian site, sandchar and elevation are significant variables for dominance of *Cynodondactylon* whereas riparian site, sandchar, channel considered as significant variables on habitat suitability of *Koeleriamacrantha* in Table 2. In Kapastikri segment, moist sand, dry sand, sandchar, channel, slope and elevation are significant variables on dominance of *Cynodondactylon* whereas dry sand, riparian site, sandchar, channel, slope and elevation considered as significant variables on habitat suitability of *Koeleriamacrantha* respectively in Table 2 (see Supplementary Tables 1–6).

It can be stated that elevation as only high significant variable to dominance of *Cynodondactylon* species in Lalgarh, Mohanpur and Kapastikri while riparian site, sandchar as low significant variables of *Cynodondactylon* dominance in three selective segments. On the other hand, another dominant species of *Koeleriamacrantha* commonly signifies by sandchar deposition in three different sites. In spite of sandchar deposition, riparian and elevation

Table 2 Derivation of coefficient with significance values of input variables layer on *Koeleria macrantha*' and Cynodon dactylon species dominance in three different segments using MLR

Segment	Species	Dominant variables								
		Wald test	Moist sand	Dry sand	Riparian	Sandchar	Channel	Elevation	Slope	Constant
Lalgarh	Km	Sig.	0.996	.000***	.064*	.002**	.000***	.000***	.050**	.000***
		ß co.	− 19.201	− 4.459	0.245	0.412	− 2.343	0.006	0.008	− 1.398
	Cd	Sig.	0.996	.000***	.000***	0.138*	.000***	.000***	.000***	.000***
		ß co.	− 17.887	1.204	1.027	0.293	− 0.875	0.02	− 0.028	− 3.563
Mohanpur	Km	Sig.	–	0.005**	0***	0***	0***	0***	0.003**	.000***
		ß co.	–	0.586	− 1.846	− 3.711	− 6.784	0.047	0.022	− 1.1
	Cd	Sig.	–	0.991	.000***	.000***	0.983	.000***	0.903	.000***
		ß co.	–	− 17.785	2.02	3.696	− 16.269	0.172	0.002	− 11.189
Kapastikri	Km	Sig.	0.995	0***	0***	0***	0***	0***	0***	.000***
		ß co.	− 17.53	− 1.312	0.984	1.239	− 1.363	− 0.071	0.203	− 2.853
	Cd	Sig.	0***	0***	0.995	0***	0***	0***	0***	.000***
		ß co.	− 0.071	0.203	− 17.53	0.984	1.239	− 1.312	− 1.363	− 2.853

**Correlation is significant at the 0.05 level (1-tailed); ***Correlation is significant at the 0.01 level (1-tailed); Km—*Koeleria macrantha*'; Cd—Cynodon dactylon species dominance; Sig—Significance level; ß co—ß coefficient

regarded as significant variables to colonize of *Koeleriamacrantha* along the river bank site.

4.3 HSI of *Koeleria macrantha* in pre mining and post mining phase along the bank site

Habitat suitability of two dominating species i.e. *Koeleriamacrantha* and *Cynodondactylon* are largely determined by intersecting of seven input parameter layers based matrix in each segment whereas degradation or alteration of three tier suitable sites caused by expanding sand mining assess by HSI integrating with MLR. HSI model based 'habitat suitable map of *Koeleriamacrantha* is classified into five categories i.e. very high suitable, high suitable, moderate suitable, low suitable and very low suitable class following land suitability class in Fig. 7a–c. Most of the river bank area covered with low suitable class in Lalgarh (3.2 km^2), Mohanpur (2.5 km^2) and Kapastikri (7.3 km^2) whereas very high suitable class has a limited area in Mohanpur (0.28 km^2) and Kapastikri (0.03 km^2) except Lalgarh (1.76 km^2) in Table 3. On the other hand, maximum sand mining area concentrated in low suitability class as Mohanpur (0.73 km^2) and Kapastikri (0.45 km^2) but massive mining area in Lalgarh segment fall under very low suitable class (0.27 km^2). Minimum sand mining area associated in very high suitable class as Kapastikri (0.77 km^2) but Lalgarh and Mohanpur reaches in high suitable class (0.01 km^2) and moderate suitable class (0.016 km^2) in Table 3. The relationship between mining site and the suitable area has highly positive in Kapastikri (R^2 = 0.970) than Lalgarh (R^2 = 0.785) and Mohanpur (R^2 = 0.529). It can be said that mining activities give negative influence on habitat suitability across the river bank. Sandchar sites are most suitable habitat sites but mining sites are the least suitable habitat of *Koeleriamacrantha* in Lalgarh, Mohanpur and Kapastikri.

4.4 H.S.I of *Cynodon dactylon* species in pre mining and post mining phase along the riparian site

Habitat suitability map of *Cynodondactylon* has same class like *Koeleria macrantha*'s habitat class in the entire Kangsabati River (Fig. 7a–c). Maximum riparian site associated in very low suitable class of *Cynodondactylon*, extensive spread in Mohanpur (4.79 km^2), Lalgarh (4.48 km^2) and Kapastikri (9.55 km^2). While very high suitable class cover very least area across the riparian site in Lalgarh (0.008 km^2) and Kapastikri (0.05 km^2) but tiny area concentrated in Mohanpur mainly high (0.02 km^2) and very high suitable class (0.02 km^2). On the other hand, mining dominant area concentrated in very low suitable class only Lalgarh segment (0.29 km^2) but dominant mining area in Mohanpur and Kapastikri segments situated mainly low suitable (0.53 km^2) and moderate suitable class (0.23 km^2). Similarly, least mining area presence in very high suitable class as shown in Lalgarh (0.0001 km^2) Mohanpur (0.0002 km^2) and Kapastikri segments (0.00004 km^2) in Table 3. Proportionally, largest mining area under *Cynodondactylon*'s habitat associated in high suitable class (Lalgarh, 18%); moderate suitable class

Fig. 7 Habitat suitability zones of *Koeleria macrantha*, Cynodon dactylon during pre mining and mining sites on suitability zone and aquatic species live in mining pits during post mining, **a** Lagarh, **b** Mohanpur, **c** Kapastikri

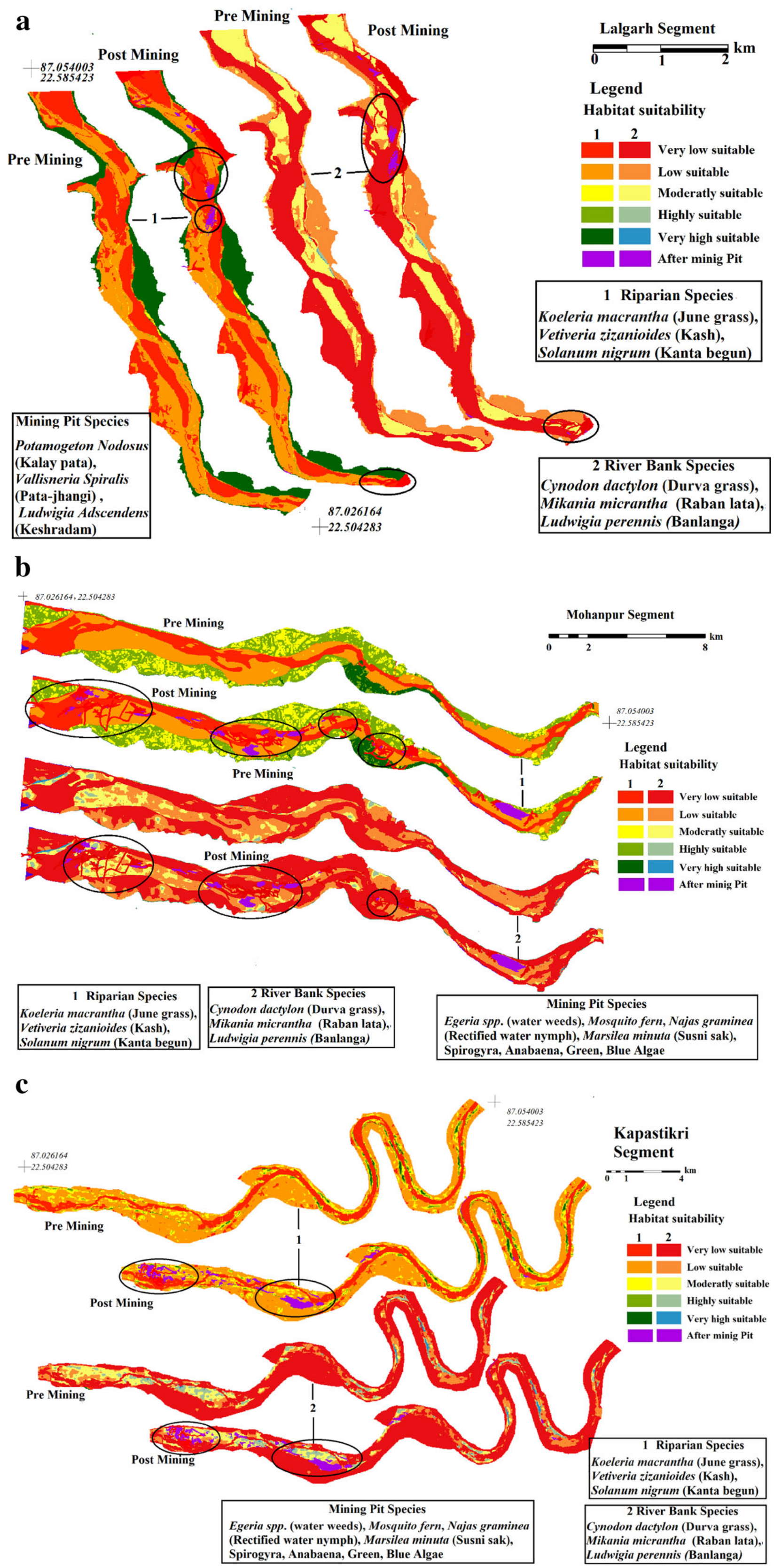

Table 3 Sand mining affected areas in habitat suitability of *Koeleria macrantha*' and Cynodon dactylon along the Lalgarh, Mohanpur and Kapastikri segments

Segment	Species	Area (km^2)	Habitat suitable class				
			Very low suitable	Low suitable	Moderate suitable	High suitable	Very high suitable
Lalgarh	Km	Pre-mining	2.98	3.2	0.05	0.02	1.76
		Post-mining	0.27	0.178	0.006	0.0001	0.038
	Cd	Pre-mining	4.48	1.81	1.77	0.02	0.007
		Post-mining	0.291	0.05	0.15	0.004	0.0001
Mohanpur	Km	Pre-mining	2.05	2.546	1.014	2.04	0.284
		Post-mining	0.25	0.73	0.015	0.074	0.03
	Cd	Pre-mining	4.794	2.2902	0.8266	0.0164	0.0166
		Post-mining	0.37	0.52	0.2	0.001	0.0001
Kapastikri	Km	Pre-mining	3.33	7.34	2.06	0.364	0.037
		Post-mining	0.145	0.44	0.152	0.011	0.0007
	Cd	Pre-mining	9.55	1.77	1.291	0.48	0.053
		Post-mining	0.197	0.23	0.26	0.05	0.00004

Km—*Koeleria macrantha*'; Cd—Cynodon dactylon species dominance

(Mohanpur, 25% and Kapastikri, 21%) whereas least mining area presence in very high suitable class (Lalgarh, 1.26% and Mohanpur, 1.13% and Kapastikri, 0.09%). There is significant positive relation between deterioration of habitat suitability and expand of sand mining area in Lalgarh ($R^2 = 0.908$) than Mohanpur ($R^2 = 0.579$) and Kapastikri ($R^2 = 0.141$). Most of the healthy *Cynodondactylon* covers are seen in sandchar dominated riparian site whereas degraded habitat site situated in mining site or exposed sand cover riparian site. Therefore, mining prone riparian site decreases soil erosion strength as well enhancing river bank erosion that can be damages *Cynodondactylon* population.

4.5 Validation of HSI of *Koeleria macrantha* and *Cynodon dactylon* species

HSI map of *Koeleriamacrantha* has observed average accuracy of 95% (Kapastikri), 90% (Mohanpur) and 80% (Lalgarh) whereas *Cynodondactylon* has overall accuracy level of 99% (Kapastikri), 97% (Mohanpur) and 90% (Lalgarh) with probability cut off at 0.5 in Table 4. Model accuracy result shows that HSI of *Koeleriamacrantha* and *Cynodondactylon* considered as an effective model in the entire study area (see supplementary Table 7-9).

TTH alteration process as well as habitat degradation sites are demarcated by habitat suitable map of *Koeleriamacrantha* and *Cynodondactylon*. Validation of two suitable map is essential to incorporate with mining intensity. Prediction rate of *Cynodondactylon* in ROC shows high probability for the occurance of TTH or habitat degradation by sand mining obtaining from Lalgarh (0.71), Mohanpur (0.81) and Kapastikri segments (0.82) in Fig. 8a–c. Prediction rate of *Koeleriamacrantha* has been found as 0.77 (Lalgarh), 0.82 (Mohanpur) and 0.72 (Kapastikri) in Fig. 8d–f. Therefore, most of the segments have reaches successful predicting power on HSI of *Cynodondactylon* and *Koeleriamacrantha* species in three segments with the value of AUC as 0.7–0.8 in ROC. Then model data set can be validated by quantitative measurement using Model Chi^2 test (LR), − 2 log likelihood Model and Nagelkerke's pseudo-R^2. Model Chi^2 test (LR) denotes that HSI model of two dominant plant species had high significant probability capability in three segments whereas Nagelkerke's pseudo-R^2 had good performance for predictive probability on *Koeleriamacrantha* in Kapastikri segment ($R^2 = 0.488$) in Table 5. In spite of Model Chi^2 test (LR) and Nagelkerke's pseudo-R^2 test result, − 2 log likelihood Model shows that HSI in three segments reaches measurable position in Table 5. Significance level or ROC curve prediction result again checked after the finding of mining pit in post mining sites by GPS survey.

5 Discussion

Dry sand track, moist sand heath and rocky outcrop govern the spatial distribution of *Koeleriamacrantha* along the river valley. Recently, several anthropogenic activities like over extraction of sand deteriorated its habitat through the bank erosion [40, 44]. In this study, high or very high habitat suitable area of *Koeleriamacrantha* (river bank) entirely depends on seven dominant variables like moist

Table 4 Classification accuracy of HSI on *Koeleria macrantha*' and Cynodon dactylon in three segments

Segment	Species	Prediction		Overall percentage
		Absence (0)	Presence (1)	
Lalgarh	Cynodon dactylon	8222	981	89.3
	Koeleria macrantha	7341	1861	79.8
Mohanpur	Cynodon dactylon	8911	239	97.4
	Koeleria macrantha	7916	814	89.3
Kapastikri	Cynodon dactylon	10,247	89	99.1
	Koeleria macrantha	14,423	734	95.2

sand, dry sand, sandchar deposition, riparian site, channel, slope and elevation in the entire segments. Contrastingly, very low and low suitable area of this species dominated in vast sand mining area due to interruption of dependable variables. Most of the high suitable class of *Koeleriamacrantha* observed in upper segment with the presence of massive dry sand deposition, channel propagation, bank elevation with steep slope across the river bank side whereas least suitable site observed in middle and lower segments with the presence of low signifies variables i.e. dry sand deposition, slope and absence of moist sand layer during pre-mining. On the contrary, very low and low habitat suitable habitat generated in lower and middle segment than upper segment due to continuously declines of dry sand, moist sand, sandchar deposition as well as interrupted riparian and bank site caused by massive sand mining than natural replenishment during post mining phase. Over extraction of sand leads to bank erosion and is deteriorated of habitat suitability in bank margin throughout the course that is justified by Table 6.

Cynodondactylon population plays leading role to increase the soil erosion resistance, strength as well enhancing the river bank stability across the transition site between river bed and bank. Water level fluctuations in channel, moist sand and riparian environment are major impact variables on the distribution of *Cynodondactylon* whereas finer grain size sediment forms organic mat prolongation low flow [9, 34, 45]. Instream and flood plain sand mining hamper the flood plain landforms as well as losses of inhabitant organism of riparian site due to channel incision [46]. In this study, habitat suitability of *Cynodondactylon* has not found very much in three different sites for the absence of significance variables jointly with moist sand deposition and riparian area caused by massive sand mining. Maximum habitat suitability of *Cynodondactylon* founds in lower segment than upper and middle segments due to presence of moist sand layer, dry sand layer, sandchar deposition, channel propagation, slope and elevation. Over sand extraction than natural replenishment interrupted the riparian habitat as well as exposed clay layer with moist sand in lower segment. As a result, low-suitable habitat area drastically expanded due to extreme channel incision in the lower segment which is already justified following Table 6. Moreover, significance variables like dry sand, sandchar deposition, riparian, elevation leads to grow habitat suitability in upper segment with the presence of huge sand accumulation than sand extraction across the channel bed to riparian site. Presence of insignificance guiding variables i.e. dry sand layer, channel, and slope as well as absence of moist sand restricted riparian habitat suitability in middle segment where huge sand extraction than accumulation destroy riparian habitat suitability. In upper segment, riparian habitat suitability is continuously grown up with the presence of significance parameters as well as massive sand accumulation than sand mining. It is point that channel incision play crucial role to change the riparian habitat suitability throughout the course which is reflected from previous study in Table 6.

Model also indirectly helps to assess the sustain or alter aquatic habitat with the presence of three prime mining responses i.e. river bed degradation, pool-riffle alteration and water quality change on channel bed during post mining phase, which already rectified by following researchers in Table 6. Aquatic habitat suitability of channel is characterized by pool-riffle alteration process through the conversion from structural knick point into mining pits or pool, which may span the channel during hosting tranquil or standing low flow stage [46]. Alluvial pools are alternating in the deep area of channel along an undulating longitudinal bed profile [47]. Pools tend to be narrower than riffles and act as sediment storage zones where much aquatic community generated with the presence of nutrient pools and high dissolved oxygen. Textural pattern of suspended sediment leads to generated two different size aquatic phytoplankton's in mining pits such as macro phytoplankton lives in coarse sand and micro phytoplankton live in finer sand [48, 49]. In study area, fifty eight pits are generated in three segments (Lalgarh 5, Mohanpur 26 and Kapastikri 27) during post mining phase (D L and LRO Paschim Midnapore and Bankura, WB 2002–2014) (Fig. 7a–c) whereas coarse grain sand

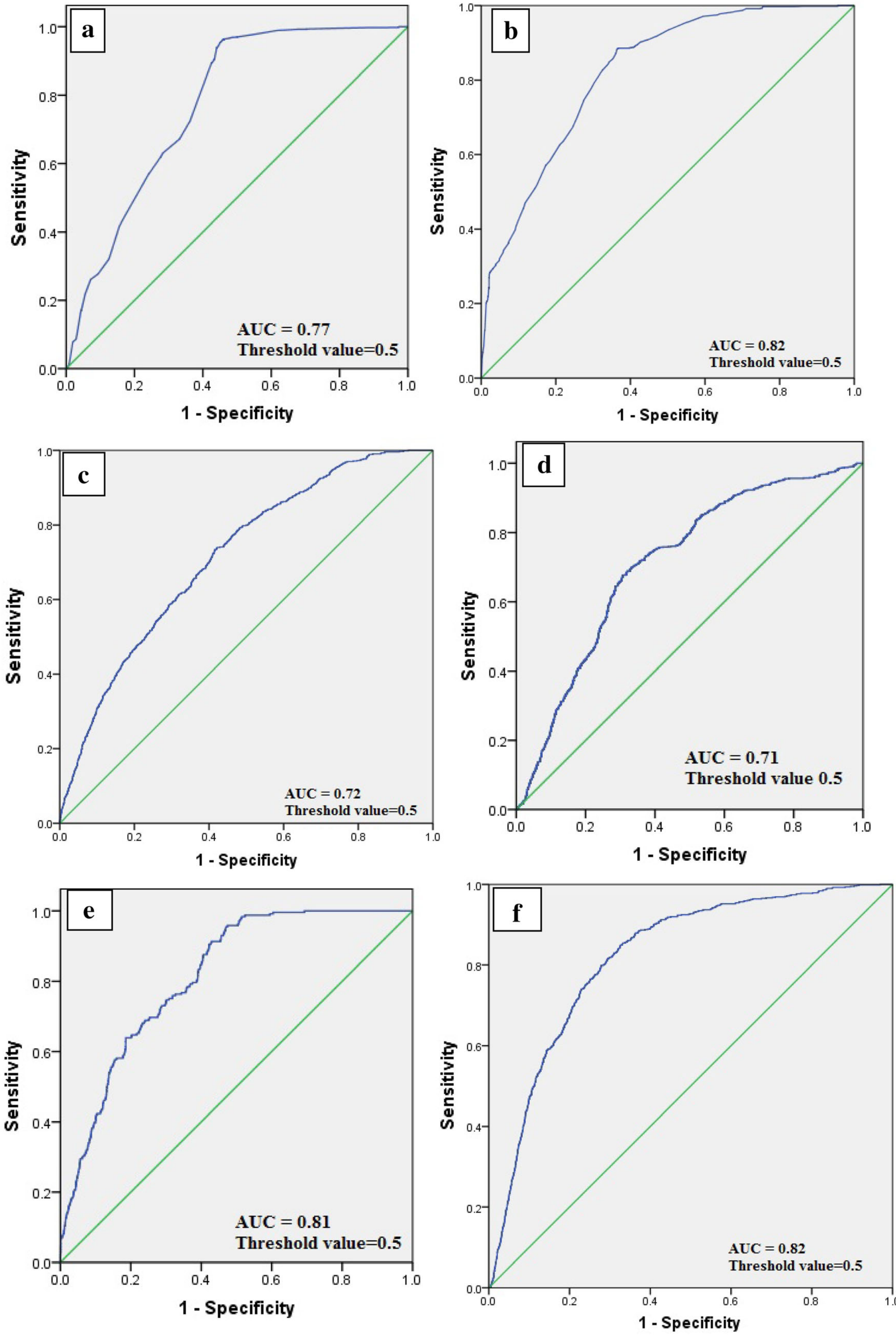

Fig. 8 ROC shows the validation habitat suitable index, **a** *Koeleria macrantha* in Lagarh, **b** *Koeleria macrantha* in Mohanpur, **c** *Koeleria macrantha* in Kapastikri, **d** *Cynodon dactylon* in Lagarh, **e** *Cynodon dactylon* in Mohanpur, **f** *K Cynodon* dactylon in apastikri

Table 5 Model summary of binary multiple logistic regression analysis in three different segments

Segment	Species	− 2 log likelihood Model	Model Chi^2 test (LR)			Pseudo-R^2	
		Model	Chi-square	*df*	Sig	Cox and Snell R^2	Nagelkerke R^2
Lalgarh	Cynodon dactylon	5751.234[a]	494.622	7	.000***	.052	.106
	Koeleria macrantha	7301.671[a]	1967.760	7	.000***	.193	.303
Mohanpur	Cynodon dactylon	1877.038	351.72	6	.000***	0.038	0.174
	Koeleria macrantha	4938.363	1485.173	6	.000***	0.15	0.297
Kapastikri	Cynodon dactylon	5434.912	441.632	7	.000***	0.029	0.089
	Koeleria macrantha	536.716	486.876	7	.000***	0.046	0.488

Table 6 Biological consequences of sand mining on three tier habitat degradation or alteration from river bank to riparian and bed following previous literature

Mining response	Biological consequences	References
Response of river bank erosion on river bank habitat (TIER I)	Floodplain sand mining leads to bank collapsing which can be destructed local flora and fauna at the outer margin of riparian site. Unrestricted sand mining merges in between two adjacent pits causes of instability on riverbank and riparian vegetation during monsoon season. Mining vehicles can damages bank site as well as losses of vegetation cover. Moreover, massive sand mining reduces water table which can be decline the widespread vegetation cover from riparian to bank margin	[2–4, 46]
Response of channel incision on riparian habitat (TIER II)	Invasion of plant species or hindrance of riparian wildlife community caused by channel incision. According to Kondolf and Larson [46], riparian woody cover drastically reduces from 340 to 151 ha near the meandering bend in rich 4, San Luis Rey River (1928–1978)	[2, 6, 46]
Response of river bed degradation on aquatic habitat (TIER III)	River bed coarsening hamper the life cycle of many flora and fauna in aquatic ecosystem whereas benthic invertebrates are altered from clandestine mining sites. Indiscriminate sand mining damages or changes many spawning and breeding ground as well as fragile of inland fishing ecosystem due to removing of substratum on channel bed. Moreover, macrophytes are either submerged or emerged due to removing of dredging shallow river	[2, 3, 12, 50]
Response of pool riffle alteration on aquatic habitat (TIER III)	Aquatic ecosystem developed in mining pit sites with the presence of huge nutrient pools. Re-naturalizing of hygrophilous aquatic vegetation into water near pit ponds initiated marsh habits in mining sites. Moreover, aquatic ecosystem either degraded or initiated or altered by sand mining	[10, 45, 46, 49]
Response of water quality change on aquatic habitat (TIER III)	Increased turbidity and suspended sediment but low dissolved oxygen causes of fish population migration and reduces of benthic invertebrate's composition	[6, 12, 48]

concentrated in upper, medium sand in middle and finer sand in lower, respectively. According to G.P.S survey (2016), maximum floating or submerged micro plant phytoplankton like *Egeria* spp. (water weeds), Mosquito fern, *Najasgraminea* (Rectified water nymph), *Marsileaminuta* (Susni sak), Spirogyra, Anabaena, Green, Blua Algae found in Mohanpur and Kapastikri segments whereas macro phytoplankton like *PotamogetonNodosus* (Kalay pata), *VallisneriaSpiralis* (Pata-jhangi) and *LudwigiaAdscendens* (Keshradam) colonized on sandy channel bed in Lalgarh segment. It is point that coarse grain bed leads to macro aquatic phytoplankton species in upper course while medium and finer grain sandy channel bed sustained micro phytoplankton in middle and downstream. It is point that either aquatic ecosystem is grown up in the inundated pit by the supplies of nutrient pools after the trapping of suspended sediment with the presence of high dissolved oxygen or channel bed degradation reduces substratum of aquatic organism with the presence of high turbidity and suspended sediment throughout the channel.

Sand extraction gradually declines sandchar or dry and moist sand as well interrupted the riparian habitat while river bank erosion intiated across the mining sites through out the channel. In this context, maximum habitat destruction or alteration of both species occur in middle segment with the presence of vast sand mining area (14%) than upper (5%) and lower segment (6%). In spite of least mining area, interrupted riparian site hindered on habitat suitability of *Cynodondactylon* as well as initiated bank erosion give negative influences on *Koeleriamacrantha* in lower and upper segment. River bed degradation and water quality change damages on several aquatic ecosystems in mining site whereas mining pit sustain or generate many hygrophilous aquatic vegetation where pool-riffle alteration supplies huge nutrient pools (Fig. 9a, b). Therefore, TTH degradation or alteration has been occurrence from channel bed to bank due to appearing of several sand mining responses like river bank erosion (river bank habitat or tier I); channel incision (riparian habitat or tier II), river bed degradation (aquatic habitat or tier III), pool-riffle alteration (aquatic habitat or tier III) and water quality changes (aquatic habitat or tier III). Moreover, mining responses are leads to interruption on significance dominant variables of

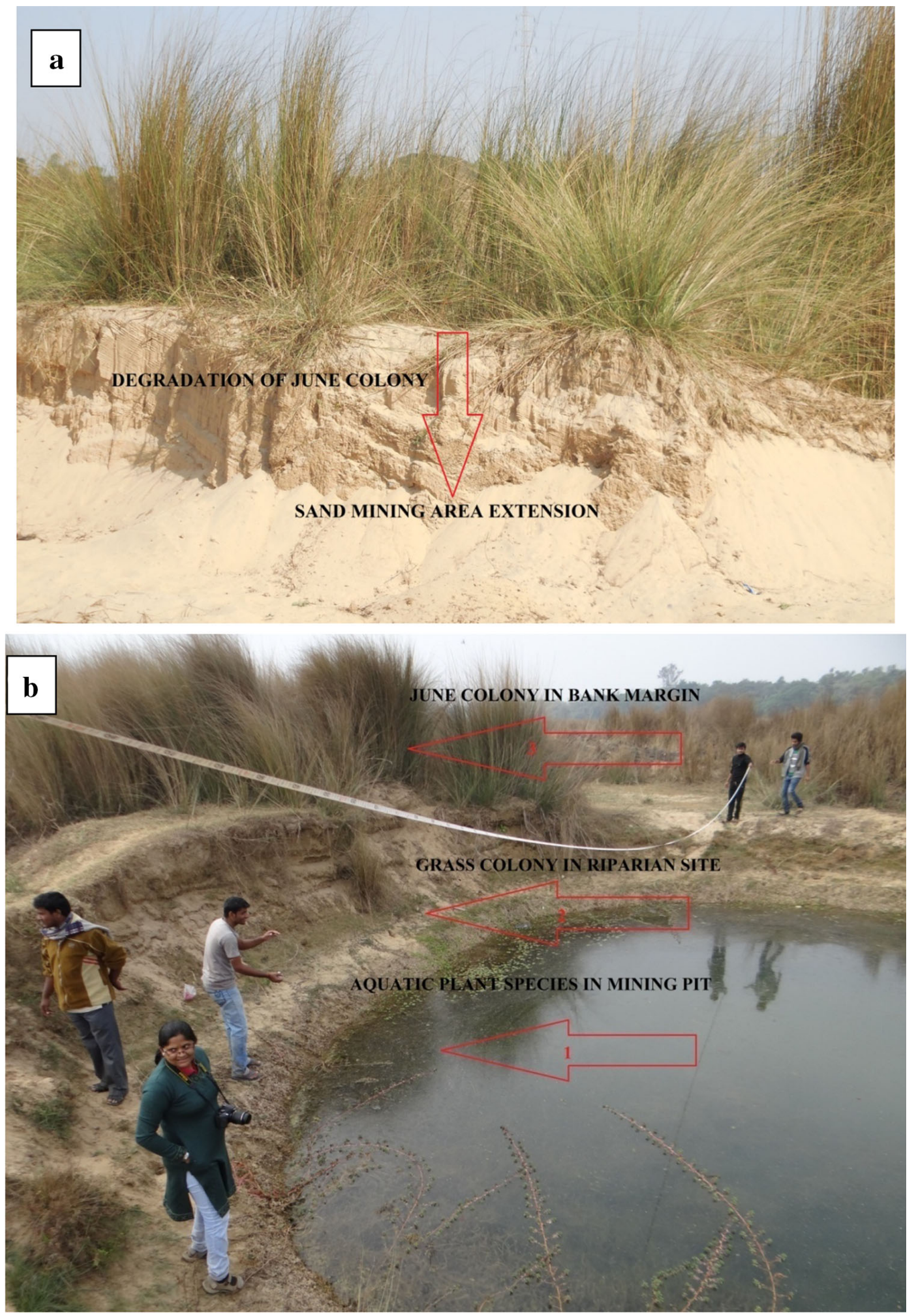

Fig. 9 Habitat degradation or alteration, **a** Habitat degradation of *Koeleria macrantha* in sand mining site, **b** three tier habitat alterations in mining pit

suitable habitat then after tree tier habitat degradation or alteration has been occurred in the entire channel.

6 Conclusion

In this study, there has discussed about two aspect i.e. determination of habitat suitability on dominant plant species such as *Cynodondactylon* in riparian and *Koeleriamacrantha* in river bank site with the following of seven variables like dry sand layer, mist sand layer, sandchar deposition, channel, riparian zone, bank elevation and slope during pre-mining phase using coupling models of habitat suitable index and binary logistic regression analysis. Another aspect as spatial pattern of habitat unsuitability incorporated with several sand mining responses during post mining phase detected by GPS survey which is justified by previous literatures. Binary logistic regression analysis helps to measure the significance test of seven thematic input variables with habitat suitability on both dominant plant species using of Wald test. Sandchar deposition, riparian, elevated bank site are significant variables on dominance of *Koeleriamacrantha* along the bank whereas moist sand layer, riparian and elevation are significant variables on dominance of *Cynodondactylon* along the riparian site throughout the course. Habitat suitability of *Koeleriamacrantha* dominant in river bank and *Cynodondactylon* dominant in riparian site assigned in three segments as upper (Lalgarh), middle (Mohanpur) and lower segment (Kapastikri) during pre-mining. HSI model reveals that unsuitable class more dominant than suitable class throughout the studied segments during post mining phase. Model result is validated by obtain predicting power from suitability index ranges of 0.7–0.8 under ROC along with quantifies measurement. Contrastingly, massive sand mining degraded habitat suitability or habitat transformation from channel bed to bank as well as sustain several aquatic plant species in mining pit on channel bed by the trapping of huge suspended sediment. Three tier habitat alterations has been occurrence through the mass failure of river bank or bank erosion and erased of riparian area caused by sand mining. Maximum transformation is seen in mining sites in three segments due to excessive sand mining. Thus the study shows that in situ habitat suitability of dominant species gradually reduces and they try to shift from mining to stable sandchar sites. Therefore, mining should be checked for the protection of river bank as well as sustain habitat suitability of aquatic, riparian and bank dominant plant species.

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