Chapter 6 Results and Discussion

6.1 Land use / Land cover classification

Supervised image classification was performed to generate Land use / land cover classification map targeted to model rhino habitat suitability study (Fig. 6). Sal forest (46%) is the dominant vegetation cover type in the landscape AOI selected for the habitat study. However, within the park area sal forest constitutes 55% of the total area. Grassland occupies the smallest area (4%) in landscape selected and 6% in the park area. The classification resulted 141 km^2 grass lands within the park and bufferzone area excluding numerous small waterbodies and swamps interspersed within the grasslands. Sal forest occupies 994 km^2. Riverine forest coverage is 169 km^2, most of the patches interspersed within grassland tracts as a result of succession. Classification map statistics (Fig. 5) shows that total area of the park and buffer zone should sum to 1802 km^2 whereas designated area as per the gazette is 1682 km^2.

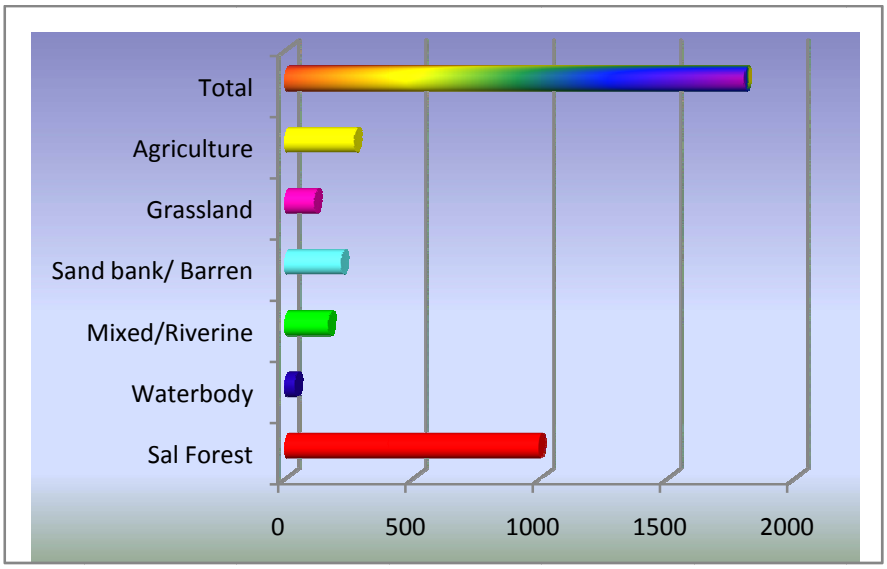

Figure 5. Area under land use/land cover categories

Vegetation classification map enabled me to analyse habitat blocks based on geometry and spatial organization of land cover types. The grassland blocks in the western part of chitwan and the eastern part are connected by dense Sal forest with narrower and fragmented belt of riverine forest. This feature is qualitatively strong barrier for movement of rhinos between two areas.

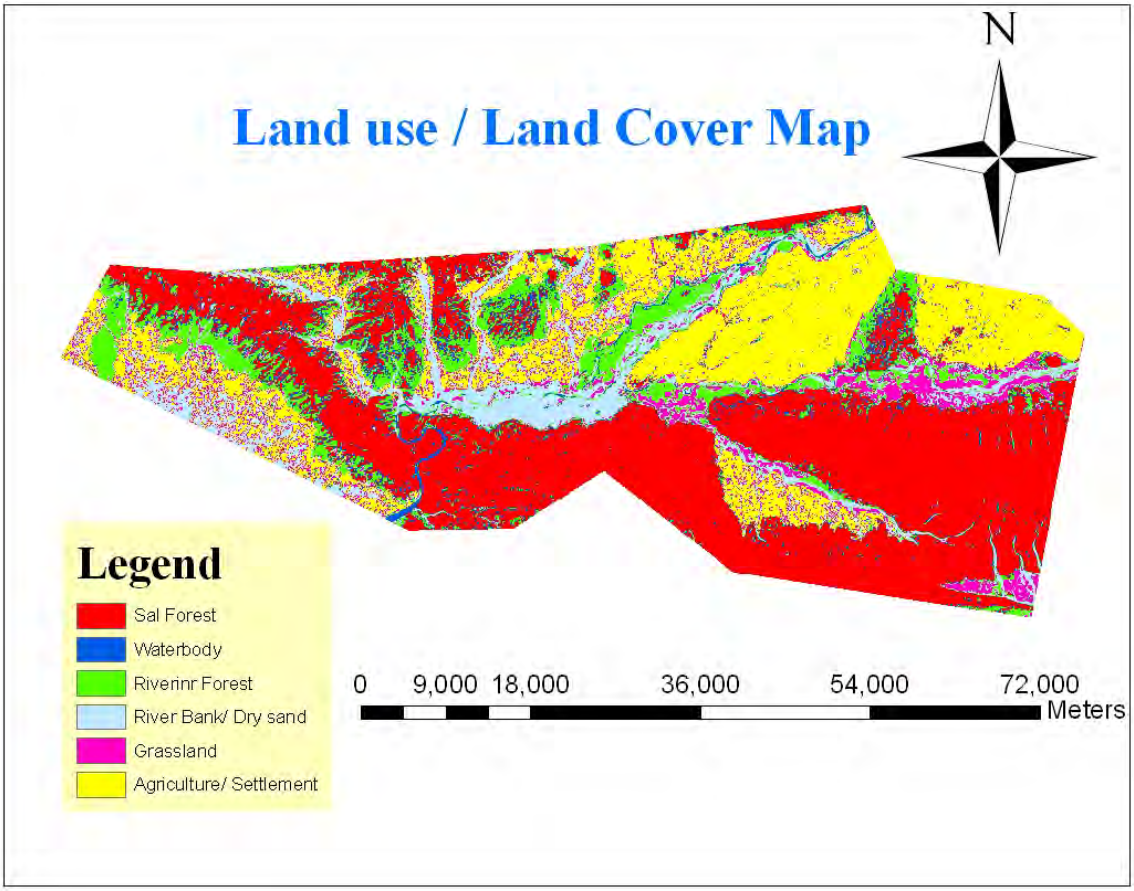

Fig 6. Land use/land cover map of Chitwan National Park and periphery

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6.2 Maxent Modeling

As mentioned above, I used Maximum entropy modeling of species geographic distributions (MaxEnt) for predicting probability of occurrence of rhinos. Continuous predictor variables as distances to Sal forest, grass lands, Riverine forest, water bodies, sand bank/ barren land and agriculture settlement and categorical land use / land cover map were used as independents in different combination to evaluate the habitat variables that effectively defines rhino presence. Preliminarily, I used all the variables as mentioned above to identify their contribution for model building and response of the variables affecting maxent prediction (Table 2). Distance from water sources showed highest (48.6%) heuristic estimate of relative contribution to the maxent model. The variable "distance from riverine forest" had least contribution (0.9%).

Table 2. Relative contribution of the independent variables to the Maxent model

S.No.	Variable	Contribution
1	Distance from Water sources	48.2%
2	Distance from Grasslands	20.0%
3	Land use / Land cover	8.9%
4	Distance from Guard posts	13.7%
5	Distance from Sal forest	2.1%
6	Distance from Riverine forest	0.9%
7	Distance from Settlement / Agriculture	6.2%

However, the response curves (Fig. 7) for the model showed fairly accurate trend for rhino suitability. Predicted Probability of rhino occurrence decreased with the increase in distance from grassland. Same was the case with distance from riverine forest and distance from water bodies. The response curve for the variables 'Distance from Sal forest and Distance from Settlement' showed that increase in

distance from these variables increases the probability of occurrence of rhinos. However, the curves showed this trend up to certain distance (approx 1km from

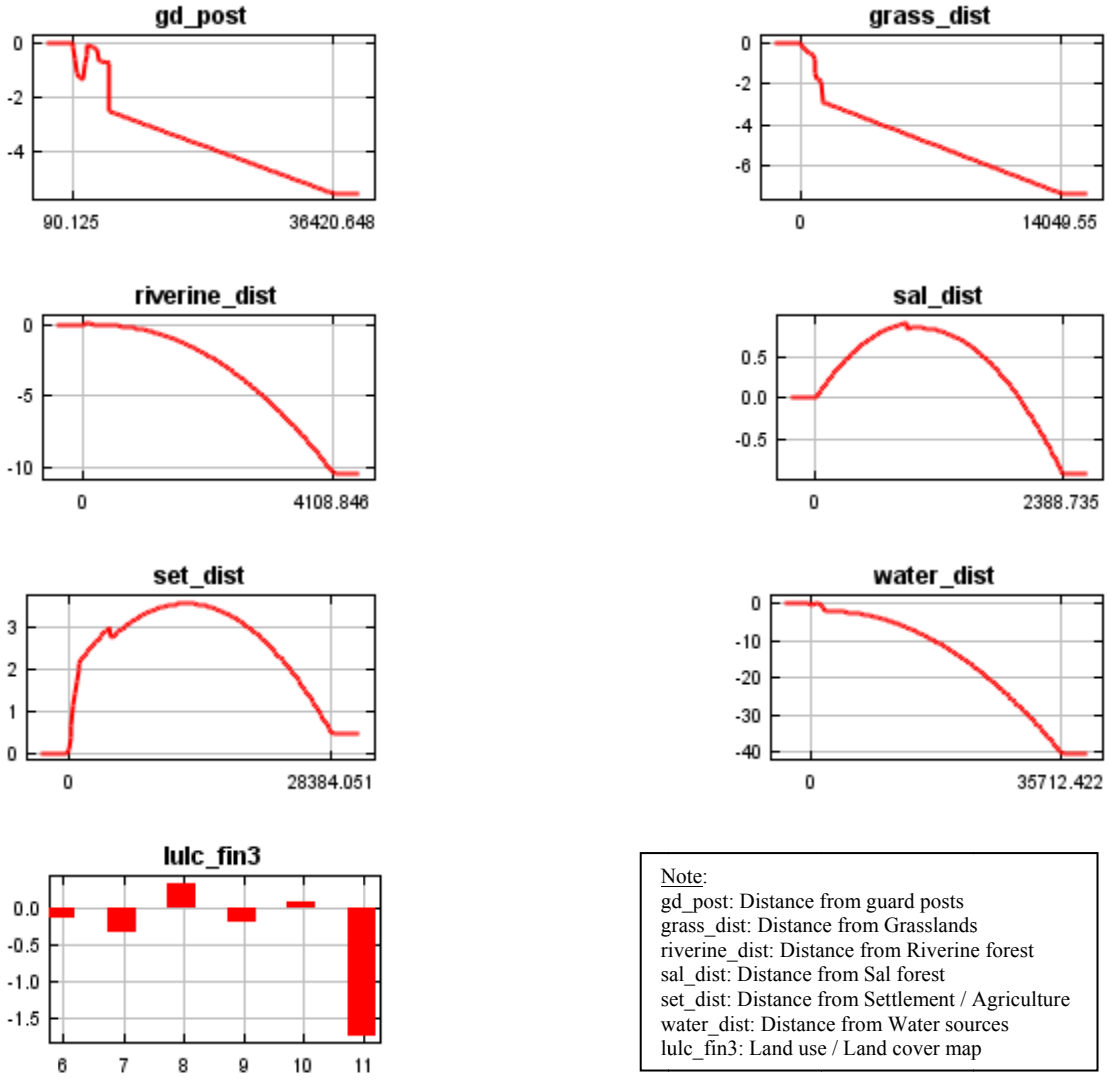


Figure 7. Response Curve of Variables affecting Maxent Prediction

sal distance and 10km from settlement distance) and beyond that the occurrence probability decreased. This may be due to the reason that there were no rhinos present beyond those distances of the respective cover types. Jackknife Test of Area Under Curve (AUC) showed least AUC (Fig. 8) when only the 'distance from riverine forest' variable was used in the model whereas it predicted very high AUC without this variable.

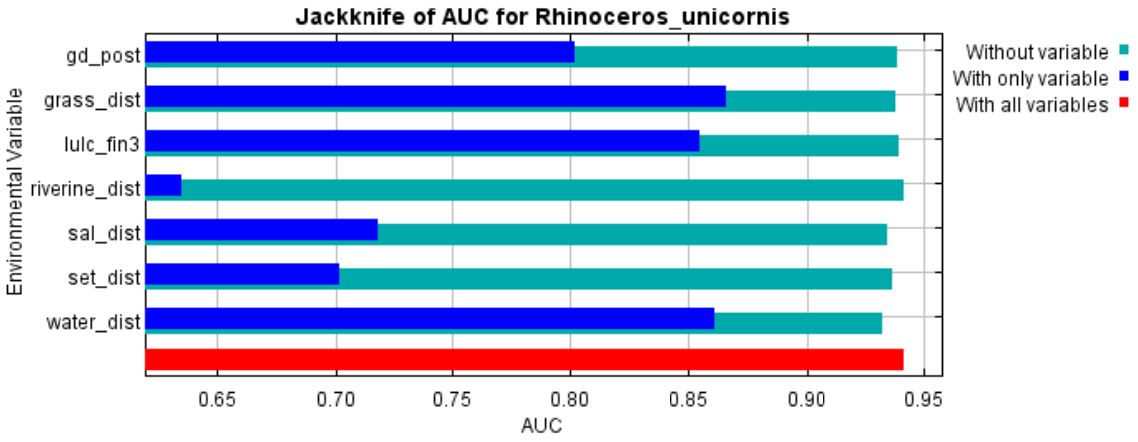


Figure 8. Jackknife of AUC for *Rhinoceros unicornis*

Same was the case with the other land cover variables viz. Distance from Sal forest and distance from settlement. However, resultant AUC was higher in the case of the variable 'distance from Grassland'. This may be because most of the rhino presence points were falling in the grassland habitat type. However, The environmental variable with highest gain when used in isolation is distance from water (Fig. 9), which therefore appears to have the most useful information by itself. Analysis of Omission rate and predicted area as a function of cumulative threshold (Philips et al. 2005) showed that omission rate was not close to the predicted omission (Fig. 10) for the model to be robust to conduct further analysis.

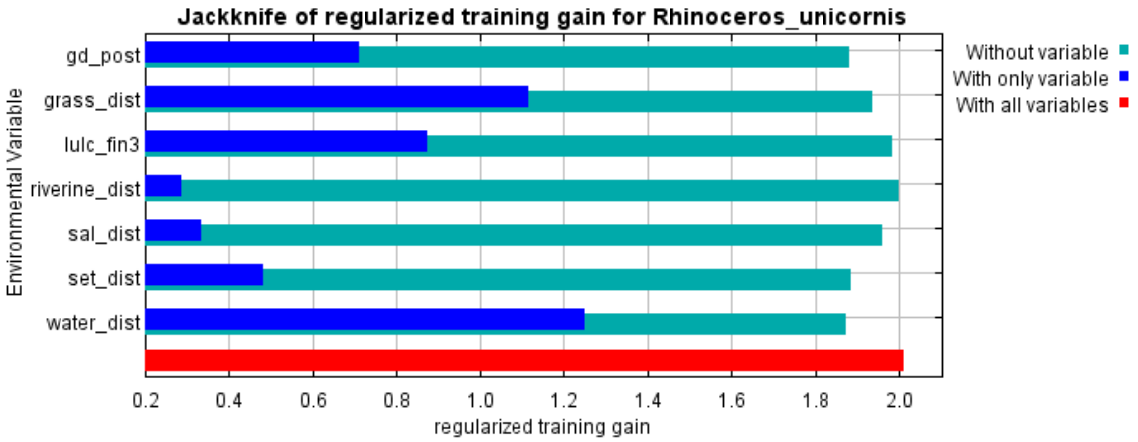


Figure 9. Jackknife of regularized training gain for *Rhinoceros unicornis*

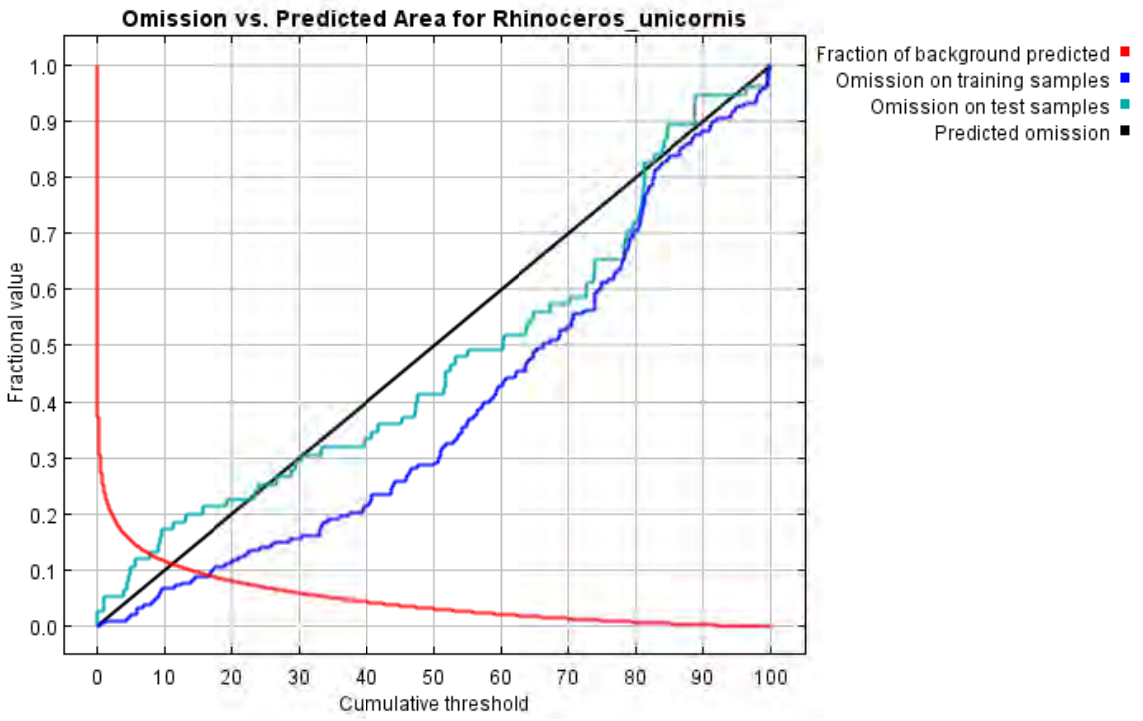


Figure 10. Omission rate and predicted area as a function of the cumulative threshold

To model with the significant habitat variables I removed all other variables that correlated with land cover map. Finally, I selected uncorrelated variables- distance from guard posts, land use/ land cover map and distance from water bodies as suitable proxies for predicting suitable rhino habitat. The distance from water body solely contributed 62.9 percent to the model. Land use/ land cover contributed 19.6 percent and distance from guard post contributed least (17.5 %). Jackknife of regularized training gain depicted that distance from water has highest gain and contained most information by itself (Fig. 11). Variable response curve (Fig. 12) predicted probability of rhino occurrence up to 35 km from the water sources. However, constant prediction probability is within the grassland and then the probability continuously decreases after about 2km from the grasslands.

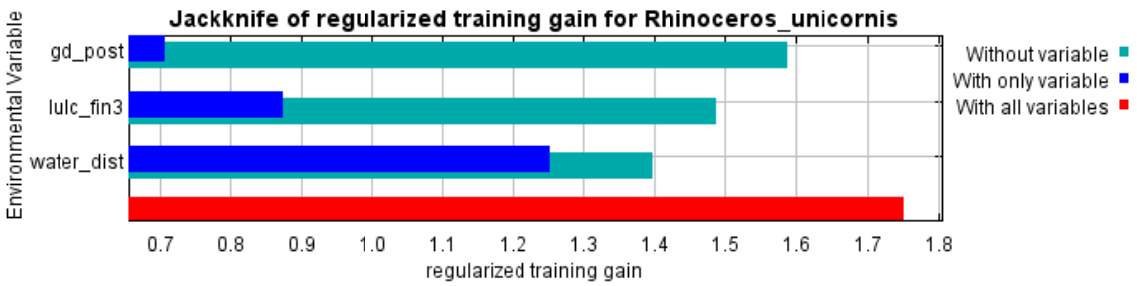


Figure 11. Jackknife of regularized training gain for R. unicornis

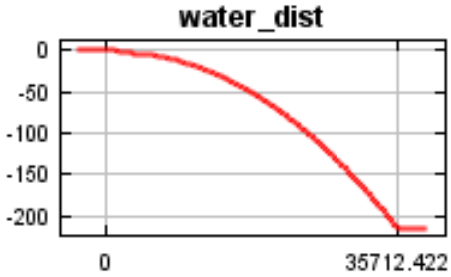


Figure 12. Response curve of variable 'Distance from water source'

The omission rate that is calculated both on the training presence records and test data, in this case, was found to be closer to the predicted omission (Fig. 13) suggesting robust model than the previous one.

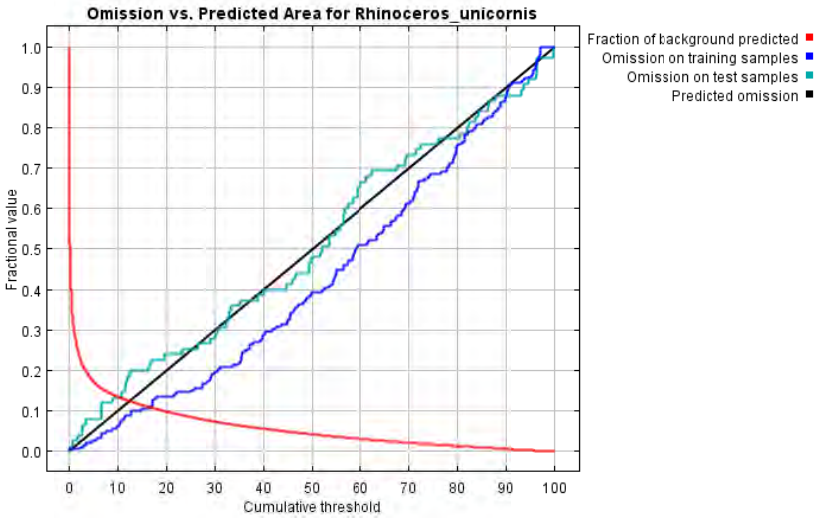
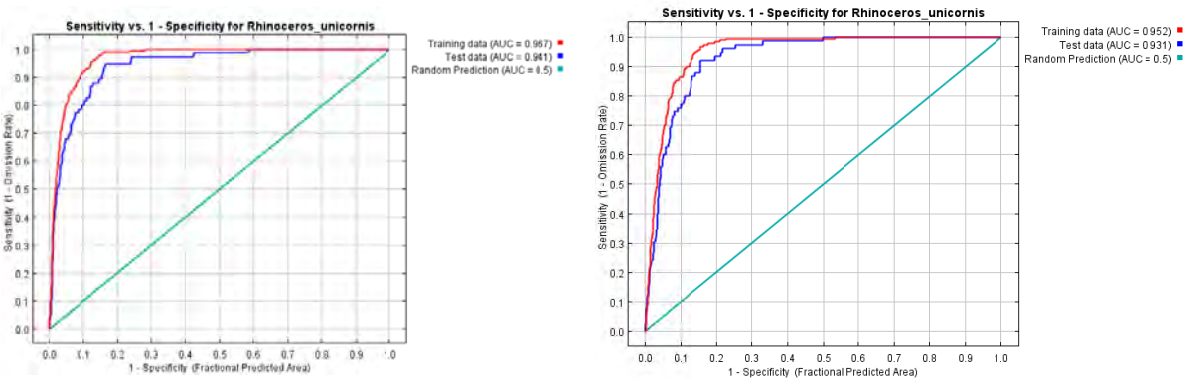


Figure 13. Omission rate and predicted area as a function of the cumulative threshold

I also used Receiver Operating characteristic (ROC) curves for analyzing the two models (Fig. 14). In the previous model the maximum achievable test Area Under Curve (AUC) was 0.950 while achieved AUC was 0.941. However in the later case, the maximum achievable test ROC was calculated to be 0.939 and the model achieved 0.931 test ROC.



A. With all variables (Ist Model) B. Uncorrelated variables (Final model)

Figure 14. Comparison of ROC Curves of the two models

Thus using AUC as a measure to compare the models the later one was found to be more precise. Therefore, I used the later model for further analysis and mapping out suitable habitat for rhinoceros.

6.1 Rhino Habitat suitability

The raw habitat suitability map (Fig. 15) shows that suitable habitat patches for rhinos in Chitwan National Park is fragmented and lacks proper connectivity for serving the animal's movement throughout its range. The warmer color in the figure below indicates the better predicted conditions for rhino occurrence. Suitability level was however assigned arbitrarily on the basis of experts' opinion.

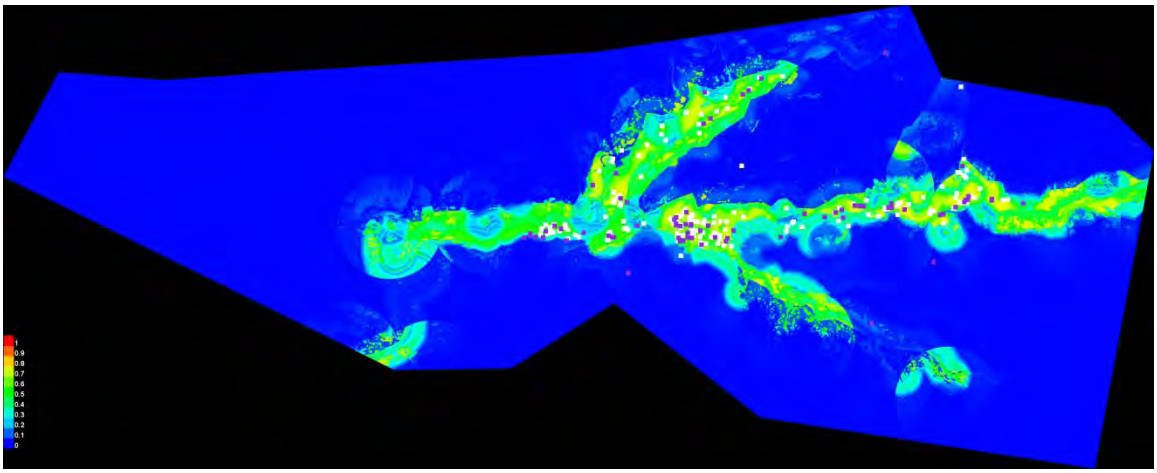


Figure 15. Maxent habitat suitability map

Firstly, I classified areas with 0-5% occurrence probability as Unsuitable, areas with 5-20% probability as acceptable (moderately suitable) and areas with 20-75% species occurrence probability as suitable habitat (Fig. 16)

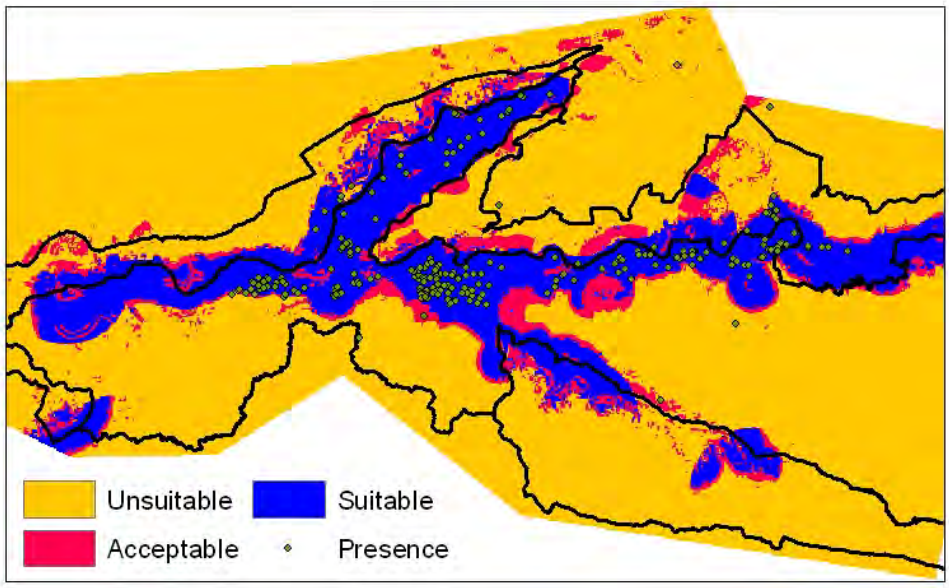


Figure 16. Three categories of habitat suitability

However, the acceptable category did not fall under any specific land use classes so that specific management intervention could be adopted for enhancing its suitability. Therefore, I reclassified the suitability map into two classes- Suitable

and Unsuitable. The areas with 0-5% occurrence probability were classified as unsuitable habitat and area with 5-75% species occurrence probability as suitable habitat (Fig. 17). This unsuitable category included the areas that have least probability for rhinos to occur.

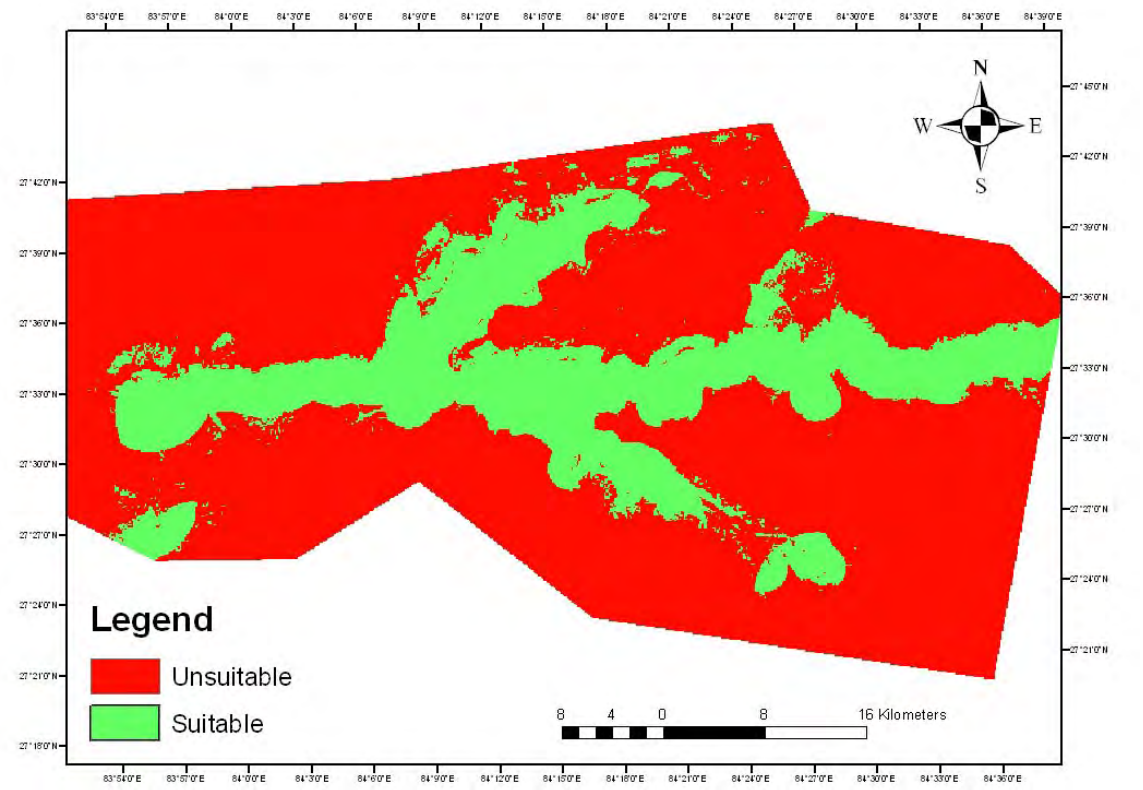


Figure 17. Suitable and Unsuitable habitats for rhinos in Chitwan National Park

While suitable category included the areas currently being used by rhinos and the areas that could be potentially used. Also it included portions of all other land cover types that were in proximity to the water sources and grasslands. The settlement and agriculture area that came under suitable category has been interpreted as the areas prone to crop raiding and human casualties. Similarly, patches of sal forest under suitable category can be viewed as the areas that can potentially harbor rhinos, if properly managed. However, these areas require intensive habitat management interventions for being used by rhinos. Based on

this classification scheme, 720 sq. km. in the park and bufferzone was classified as suitable and remaining 1082 sq.km as unsuitable (Fig. 18). Among the suitable area 73sq/km agriculture and settlement cover type, 33 sq.km water bodies and 171 sq.km Sal forest cover types are presently unavailable for rhinos. Therefore I subtracted these areas from total suitable area. Thus according to this model total suitable habitat available to rhinos at present worked out to be 443 sq.km. This area included grassland, riverine forest and sand bank/ Barren land cover types.

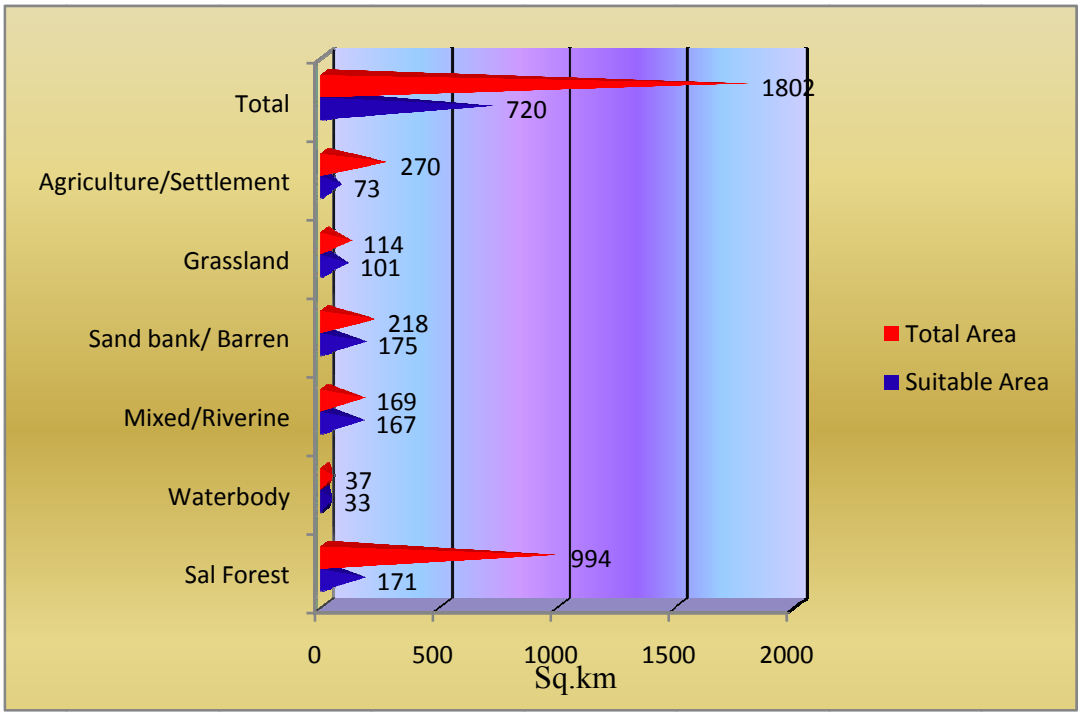


Fig 18. Area under suitability category

The maxent suitability map also shows that majority of 'suitable' patches are surrounded by patches with less species occurrence probability. Therefore for enhancing its probability habitat improvement interventions have to be carried out. This model also suggests that increasing number of water sources will help increasing suitable habitat for rhinos. This result suggests that contiguous patches under different probability of species occurrence should be worked out for

improving its suitability while prioritizing area for management intervention. The result of habitat suitability map shows that rhinos can occupy the 171 sq.km of sal forest that has been categorized as suitable. Thus total potentially suitable habitat for rhinos in Chitwan National park is 614 sq.km. However, for achieving this extent of area as suitable, number of water bodies has to be significantly increased and maintained.

Chapter 7 Conclusions & Recommendations

Evaluation of potential area for *Rhinoceros unicornis* can be considered as one of the most important steps towards the conservation of the rhinos. Rhino, being herbivore species, has greater affinity towards vegetation that serve as food for it. Its main food comprises of varieties of grass species and hence it prefers to spend majority of its time in grassland habitat. As the climatic condition, where it thrives, ranges is hot and humid, it also requires waterbodies for wallowing to keep it cool in extreme temperatures. Moreover, the grasslands it prefers are more likely to be available in the floodplains of the rivers and maintained by the periodic flood. Likely to almost all wild animals it avoids any kinds of anthropogenic disturbances. Hence availability of contiguous grasslands interspersed with sufficient waterbodies and sufficiently distant from factors of disturbances is considered as suitable condition where rhino thrives well. These all parameters for rhino habitat suitability can be detected in appropriate resolution satellite imagery with clear distinction between the features of interest. Hence, several attempts have been made to model suitability of this in favor of its conservation.

This study attempted to model rhino habitat suitability in Chitwan National Park using Remote sensing, GIS, GPS and Geostatistical techniques and elaborates its procedure for enhancing extensive use of these efficient techniques for wildlife habitat evaluation.

The results of the study revealed that 443 km^2 of the park is modeled as suitable including 101 km^2 grasslands, 175 km^2 of sand banks / barrenlands and 167 km^2 riverine forest. The patches of sal forest (171 km^2) most of them contiguous to the *Sukhibhar* grassland are also modeled as suitable owing its proximity to the source of water and perhaps due to the contiguity to the grassland with high rhino

occurrence. Thus, I conclude that if enough water holes are created and thinning operation is carried out for enhancing colonization by grassland community these patches of sal forest will serve as promising habitat for rhinos. The area under agriculture and settlement land cover class which is modeled as Suitable are potentially prone to crop raiding by rhinos.

Considering the areas used by rhinos at present and the areas modeled as suitable, I conclude that suitable habitat for rhino in the Chitwan is potentially more than that used by the species at present. If managed properly it can sustain more population than the highest 512 individuals the park harbored till date.

7.1 Conclusions

i.) In Chitwan National Park, Rhinoceros distribution was found to be dependent on the presence of water bodies. The species, with no doubt, prefers grasslands. Emergence and maintenance of grasslands along the river sides are the functions of river behavior. Beyond the distance up to which the river exerts its periodic influence during every monsoon, it is the responsibility of managers for maintaining the grasslands .

ii.) Chitwan National Park contains 443 sq.km suitable habitats for *Rhinoceros unicornis* majority of that are under grassland, sandy bank and riverine forest land cover types. There is high potential for increasing the suitable habitat areas through proper habitat management interventions.

iii.) Maxent can be effectively used for predicting species potential distribution with the help of presence-only data. Remote sensing and GIS tools are extremely useful for habitat analysis and suitability modeling of wildlife species and have immense importance in

undertaking wildlife conservation and management interventions for achieving conservation objectives.

7.2 Recommendations

i) Despite of several anthropogenic disturbances and pressures Chitwan National Park still harbors high biodiversity including large mammalian species as Tiger, Elephant and Rhinos. It has shown high potential for conservation of rhinos. Hence, rhino suitable area should be prioritized for imparting specific management interventions as creating artificial water holes, grassland management activities as controlled grass burning, and limiting tourist visits in the rhino area.

ii) Corridor development between different patches of suitable habitat should be given due consideration. Not necessarily forest patch be cleared in favor of rhino mobility by creation of forest blank which gradually develop into grassland but constructing water holes may serve for the purpose.

iii) Existing grasslands should be maintained in perpetuity through proper grassland management techniques.

iv) Easy access should be created for approaching to water bodies. Sloping approaches should be smoothened in favor of rhino accessibility to its major life requisite.

v) Accurate and official figure of the protected area should be determined for effective conservation of the wild fauna surviving in Chitwan National Park.

vi) Management of Narayani, Rapti and Reu rivers are most important for rhino conservation. Every year the flood has devastating effect to the surrounding villages. However the flood has much positive influence for

creating new grasslands and maintains it. Therefore, interdepartmental consultation may help for managing the rivers in such a way that its adverse impact is minimized and at the same time rendered beneficial for biodiversity conservation of the floodplain.

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