Modeling Drivers of Tree Cover Change in Nepal

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International meeting on Twenty-five years of community forestry:

Mapping tree dynamics in the Middle Hills of Nepal

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Modeling team

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- Centre for Development and Environment (CDE), University of Bern, Switzerland
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  - Alexander C Smith
- ICIMOD, Nepal
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Aims

- Quantify the association between migration and community forestry and tree cover
- Examine patterns across different ecological belts/regions
- Examine the scale effects in these associations – VDC vs District level
  - Academic and practical motivations

Main variables: Dependent

- % land under Tree Cover (TC), estimated by OSU-CDE team
- Growth rates and differences in %TC

Main variables: Independent

- Migration
  - % of adult males who are absent from the village
- Community Forestry (CF)
  - % of forest land under CF
  - % of households participating in CF
  - % members in CF
  - % women members

Other variables that need to be accounted for

- Bioclimatic
- Terrain and topography
- Biogeophysical (BGP)
- Socio-economic

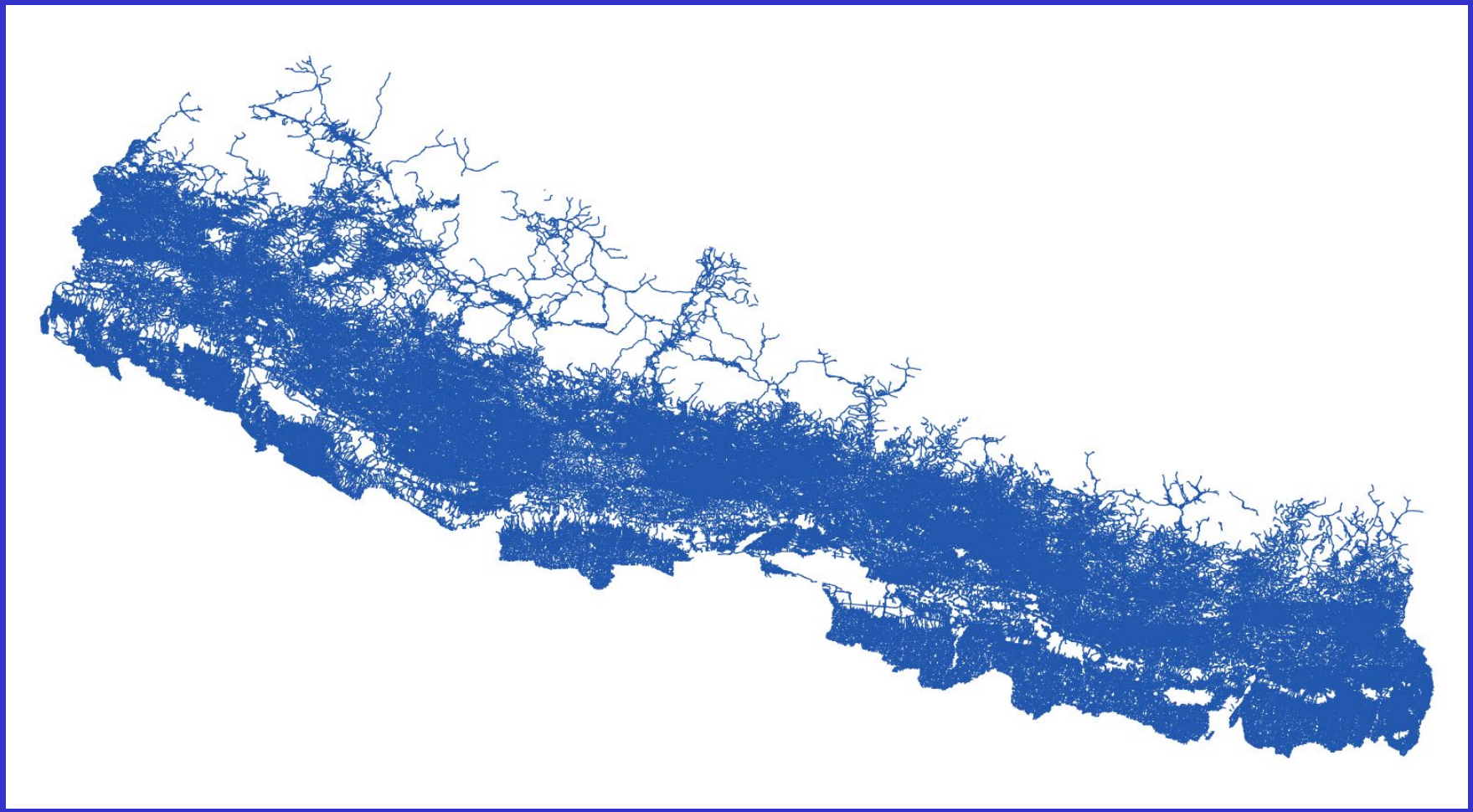
Data Sources and Estimations

- Base GIS layers of administrative boundaries – Humanitarian Data Exchange
- 19 Bioclimatic variables: WorldClim ver.2 , 30-seconds resolution (1 km^2)
- Demographic: Central Bureau of Statistics, Census 2001 and 2011, VDC level data
- Water bodies - River Network of Nepal. Kathmandu, Nepal: ICIMOD

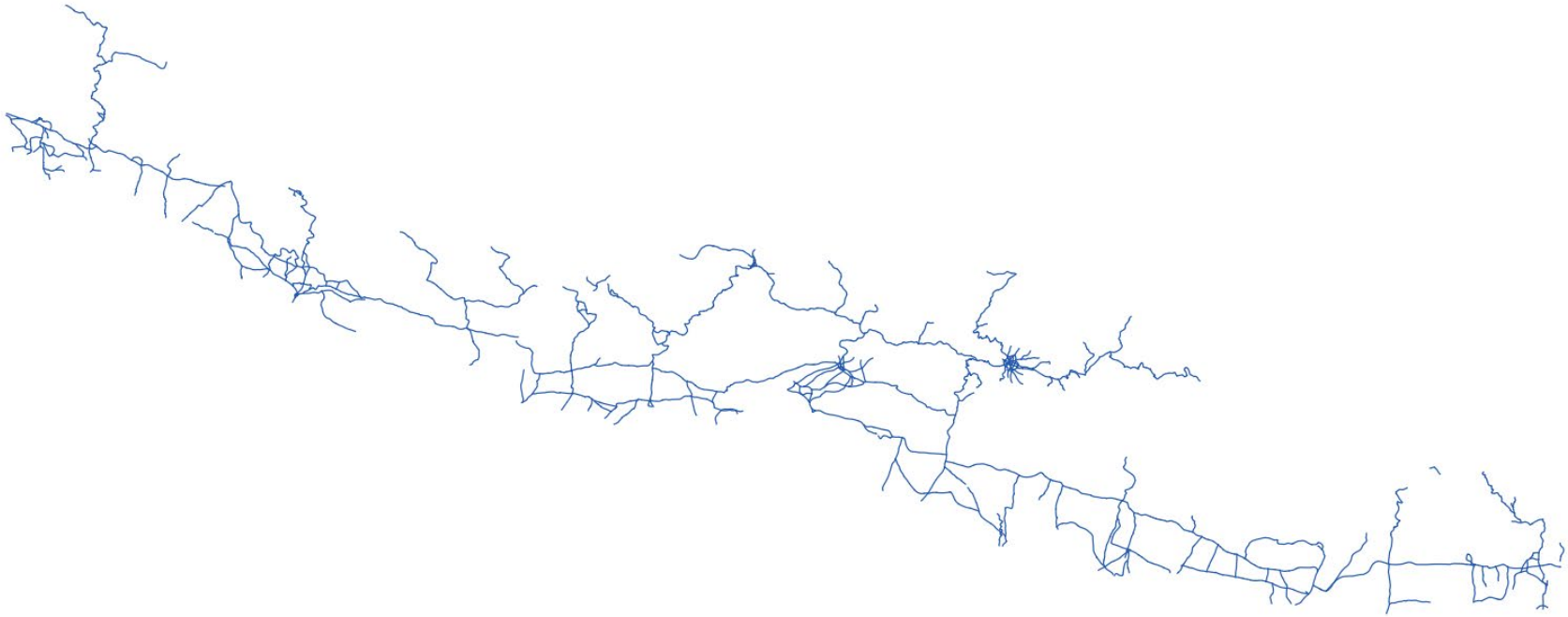
Data Sources and Estimations

- Distance to nearest major road
- Density of minor roads
- Accessibility to district headquarter

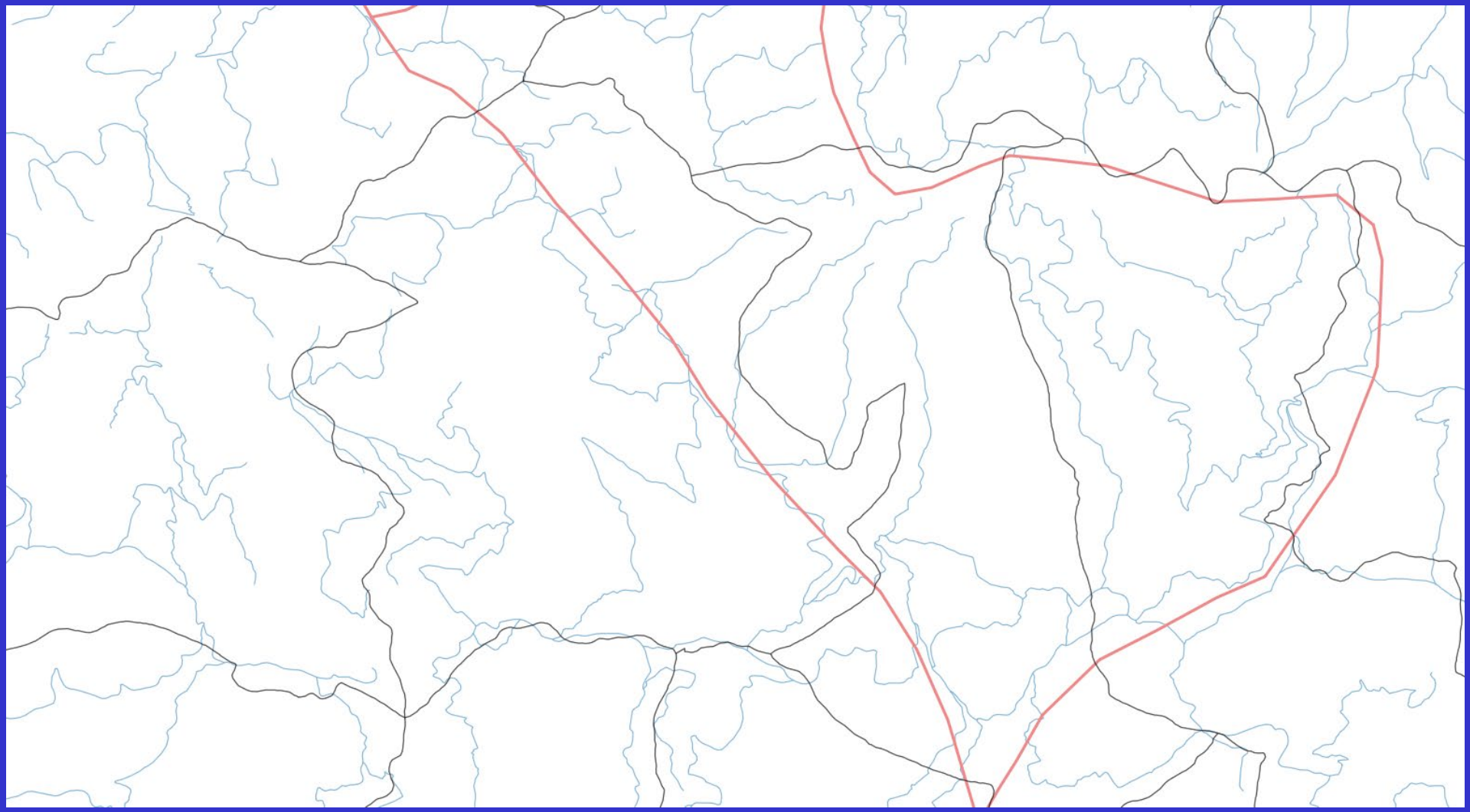
Minor Roads



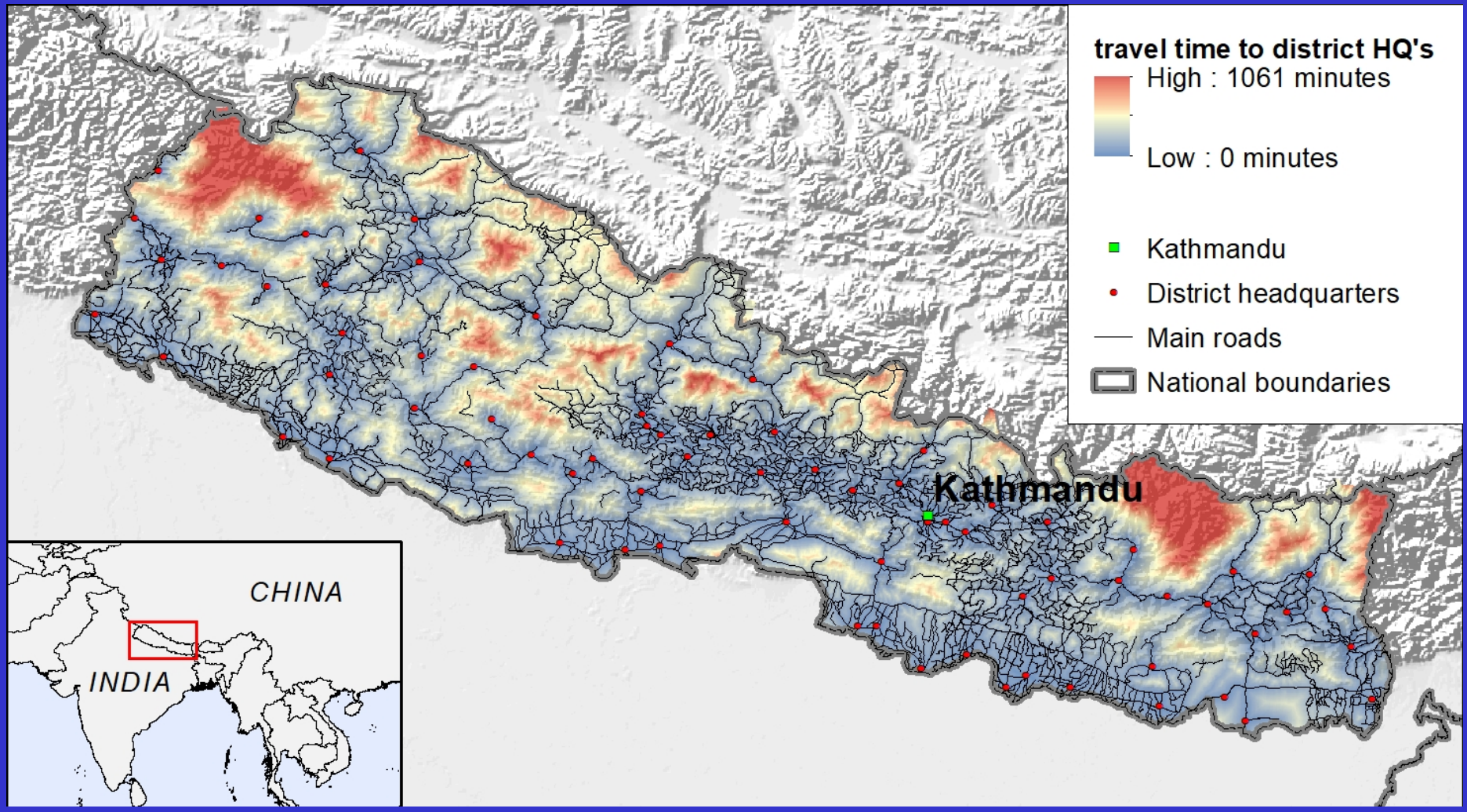
Highways, major roads



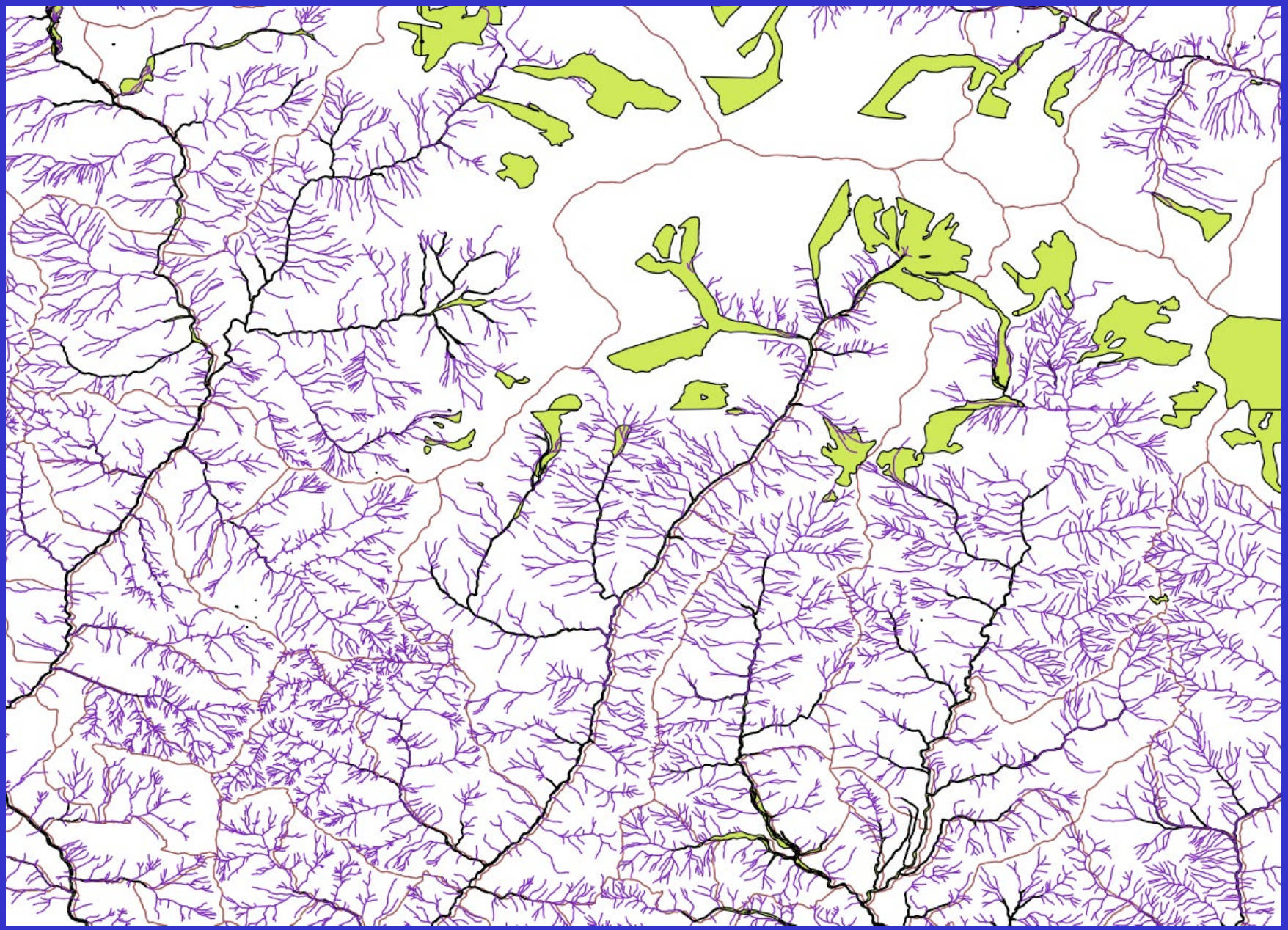
Major (red) and minor (blue) roads inside a VDC (black)



Access time to district HQ



Streams and Water bodies



Terrain and Topography

- DEM for elevation, slope, aspect – 30m SRTM
- Terrain Ruggeddness Index (TRI)
- Terrain Eastness
- Terrain Northness
- Beers Aspect
- Terrain Curvature, 30 and 90 DEM
- Topographic Position Index (TPI): local , intermediate and landscape scales

Compound Topographic Index

- Is a steady state wetness index
- The index is a function of both the slope and the upstream contributing area per unit width orthogonal to the flow direction
- highly correlated with several soil attributes such as horizon depth, silt percentage, organic matter content, and phosphorus
- Proxy for agriculture suitability

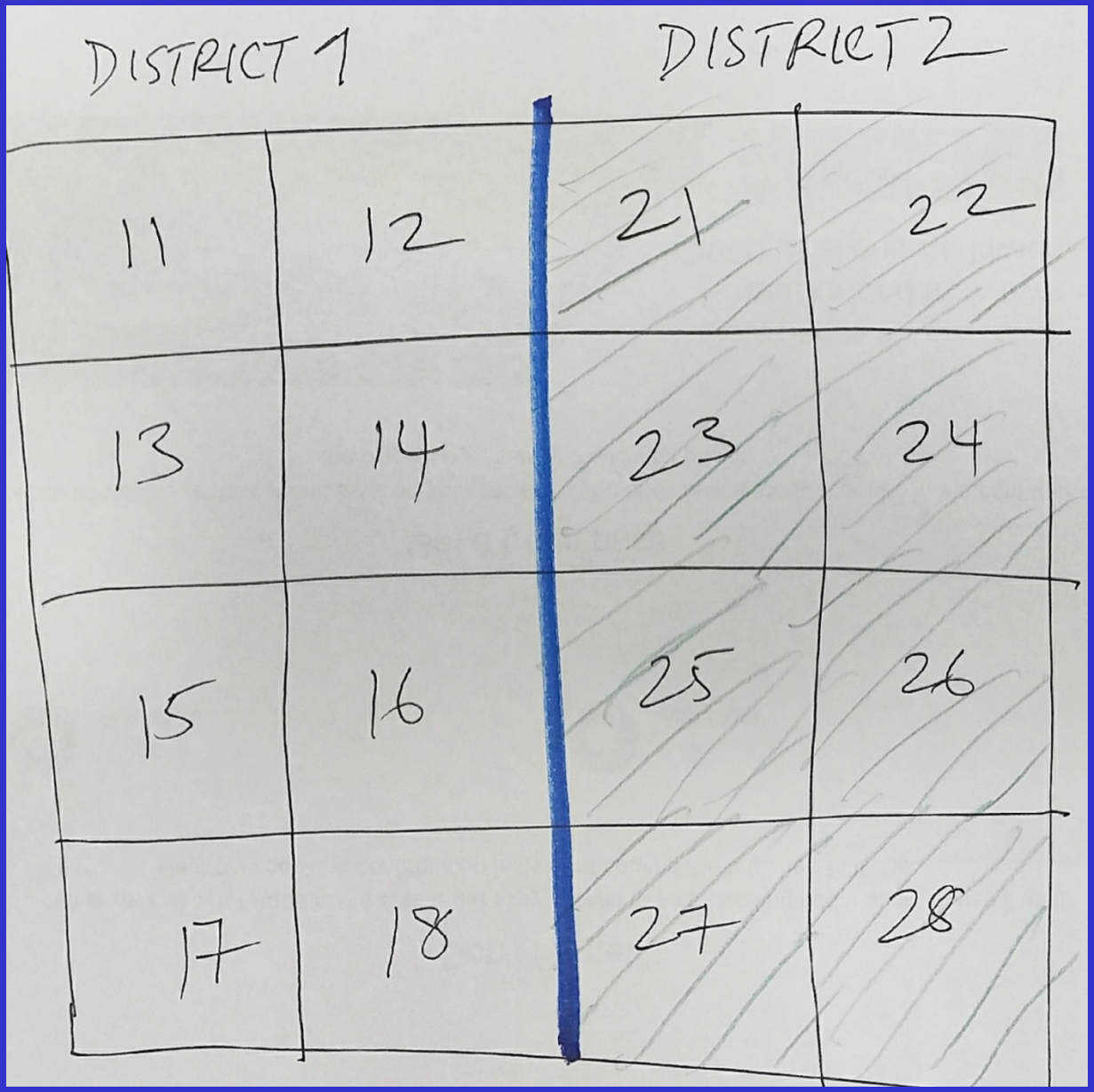
Modeling strategy

- Complex and Coupled Natural and Human Systems are best modeled using complementary techniques
- Traditional multivariate regression and Machine Learning (Random Forest) models
- Account for place-based and space-based clustering effects (auto-correlation)
- Collinearity among the independent variables

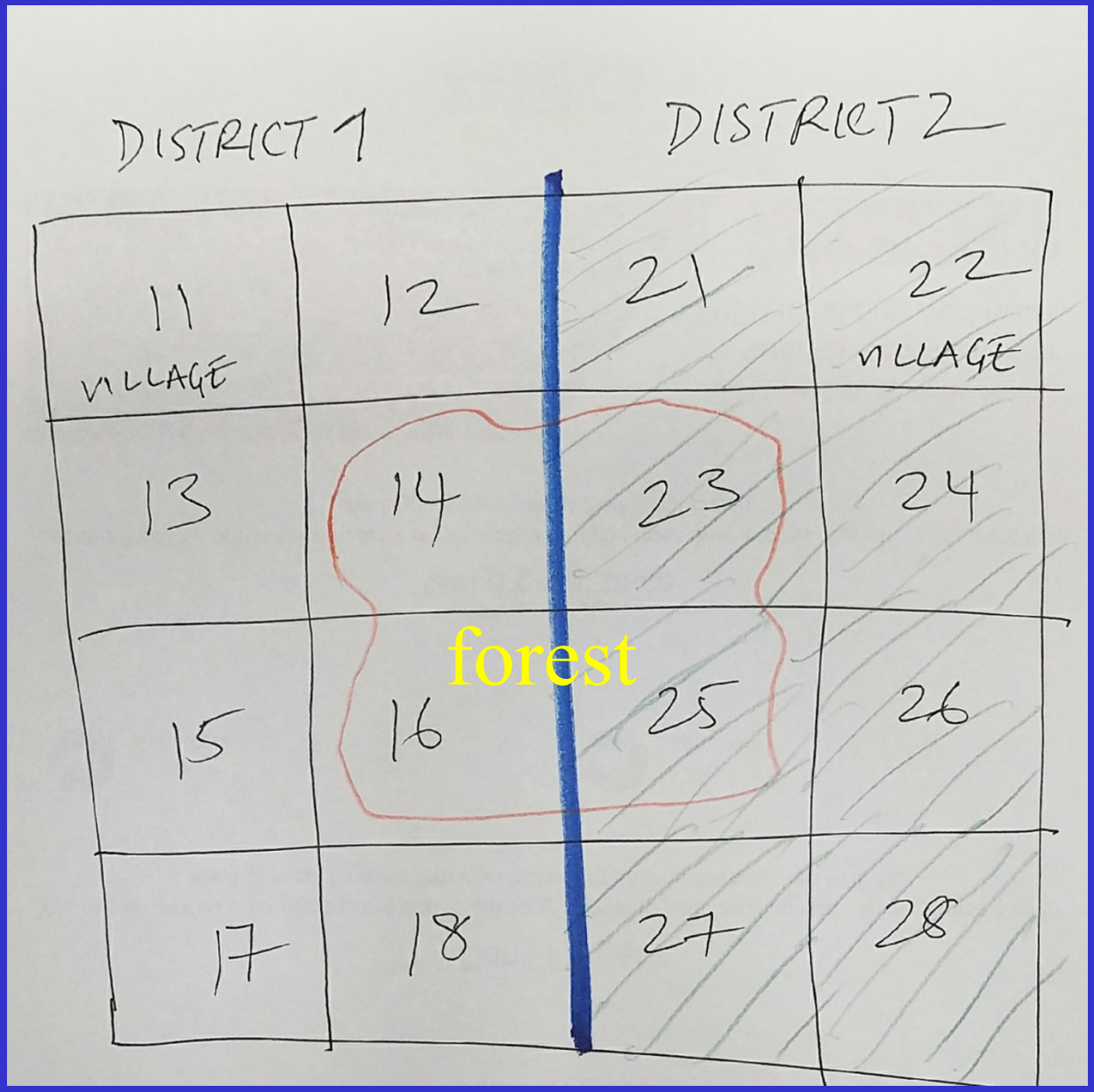
Clustering/spatial auto-correlation effects

- Social science, Place-based: Multilevel models (aka mixed effects or hierarchical models)
  - VDCs nested under a District are expected to be similar
- Physical science, Space-based: Inclusion of an auto-covariance term in regular approaches
  - Augustin et al's (1996) method: values of the autocovariate depend on the values of the response variable in the neighbourhood.
- Hybrid approach

Multilevel regression modeling



Spatial autocorrelation



Results

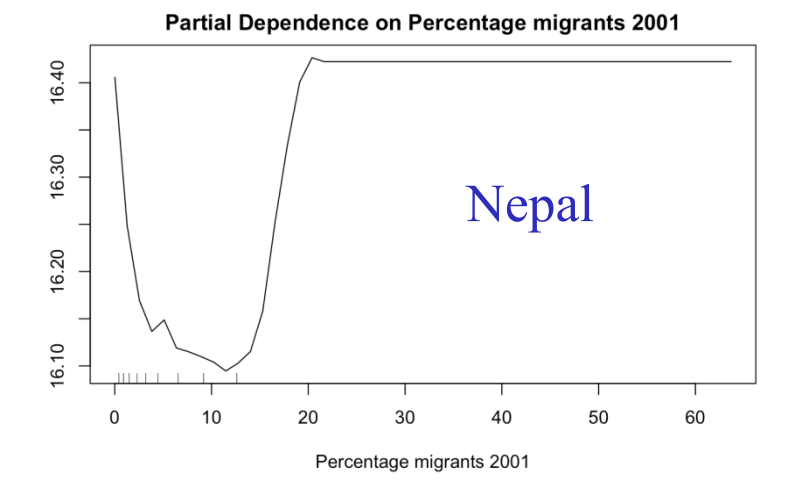
% TC 2016 minus % TC 2001
Multi-level model with spatial autocov

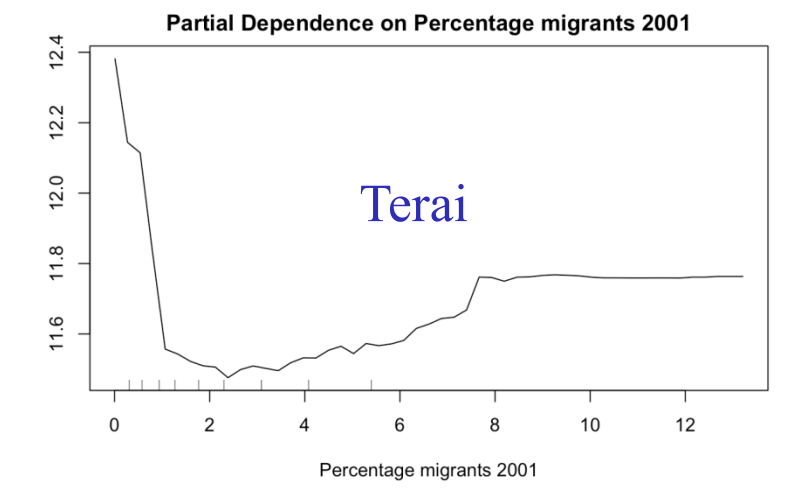
Belt Accuracy	Nepal 69%	Terai 57%	Middle Hills 67%	Himalaya 87%
Baseline TC	-	-	-	-
Population density	-	-	x	+
Modern Houses	+	x	+	X
Migrants	x	x	+	-
CF houses	+	x	+	X
Distance to Protected area	-	x	-	X
% protected area	-	x	-	X
Road density	+	-	+	X
Distance to municipality	+	x	x	X
Distance to highway	x	-	x	X
Accessibility	x	-	x	X
Compound Topographic Index	-	-	-	X
Water bodies	-	-	-	+
Terrain ruggedness	-	-	-	-
Terrain eastness	+		x	X
Terrain northness	-	-	-	X
Topograhic position -local	-	-	-	X
Temperature	+	x	+	+
Precipitation	x	x	+	x
Spatial autocov	+	+	+	+

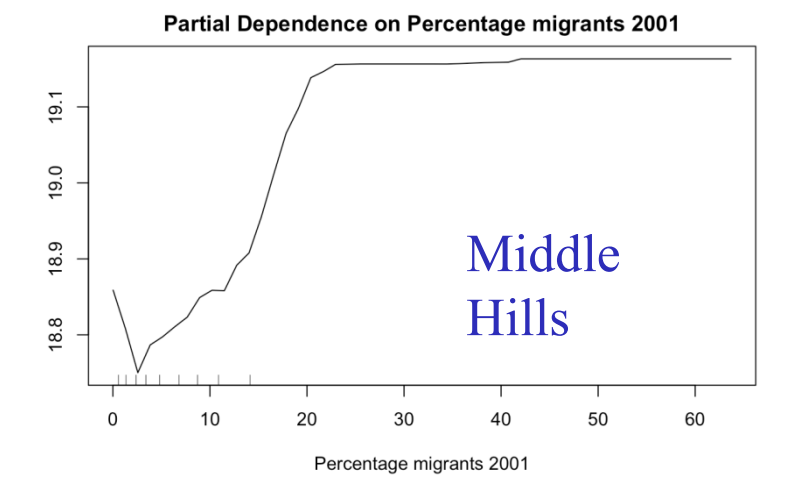
% TC 2016 minus % TC 2001
Random Forest model with spatial autocov: Top 12 influencers

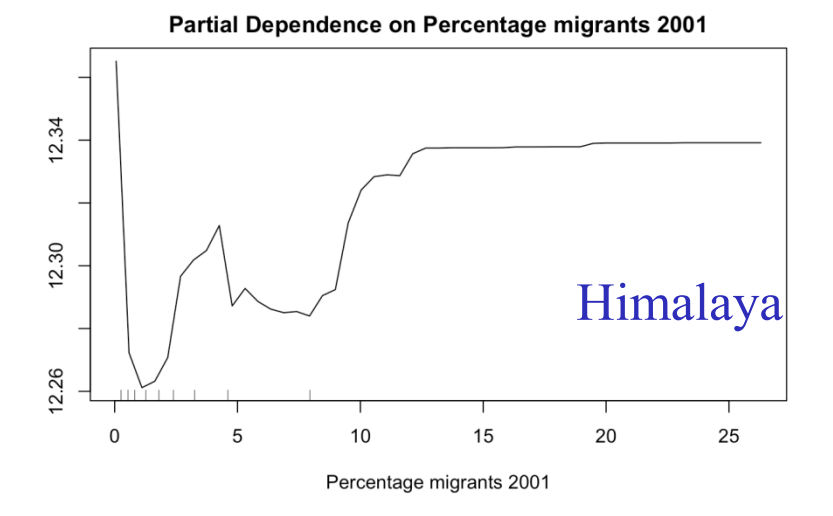
Belt Accuracy (test set)	Nepal 75%	Terai 49%	Middle Hills 67%	Himalaya 88%
Baseline TC	3	2	3	9
Population density	2	4	2	5
Modern Houses	10	5	7	
Migrants		6		
CF houses				
Distance to Protected area	11	7	10	
% protected area				
Road density	8		11	6
Distance to municipality		12		8
Distance to highway	12			4
Accessibility			12	12
Compound Topographic Index	7	11	6	10
Water bodies				11
Terrain ruggedness	6	10	5	3
Terrain eastness	9		8	
Terrain northness		3		
Topograhic position -local				
Temperature	5	8	9	7
Precipitation	4	9	4	2
Spatial autocov	1	1	1	1

Difference in tree cover between 2016 and 2001 vs. migration

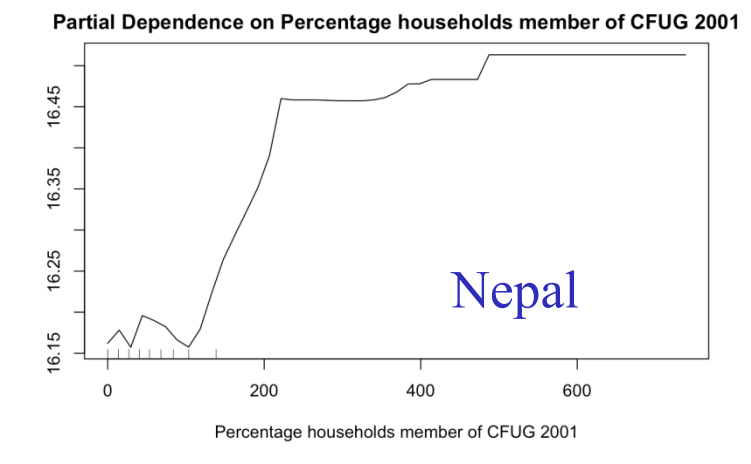


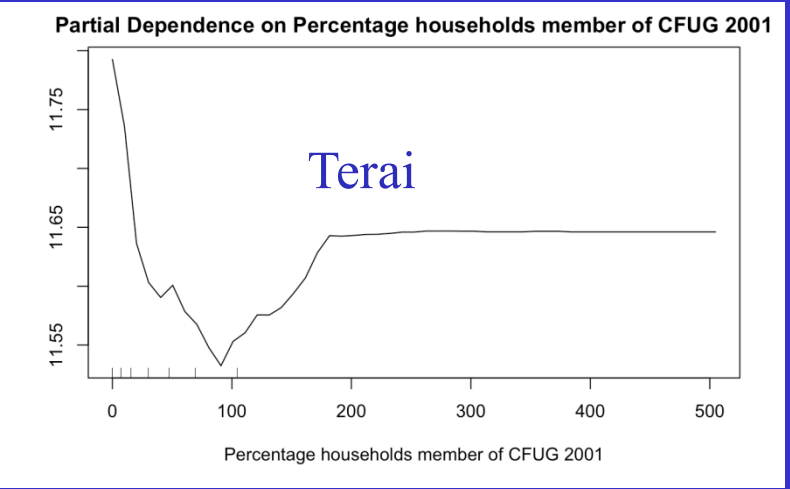


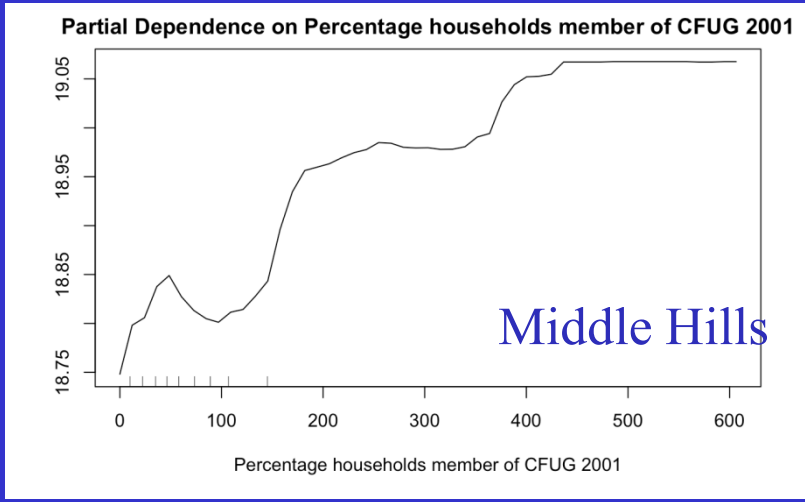


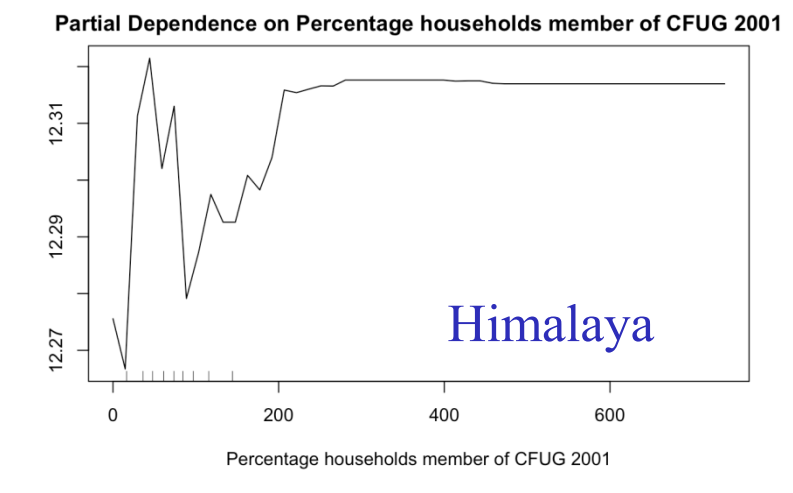


Difference in tree cover between 2016 and 2001 vs. houses in CF

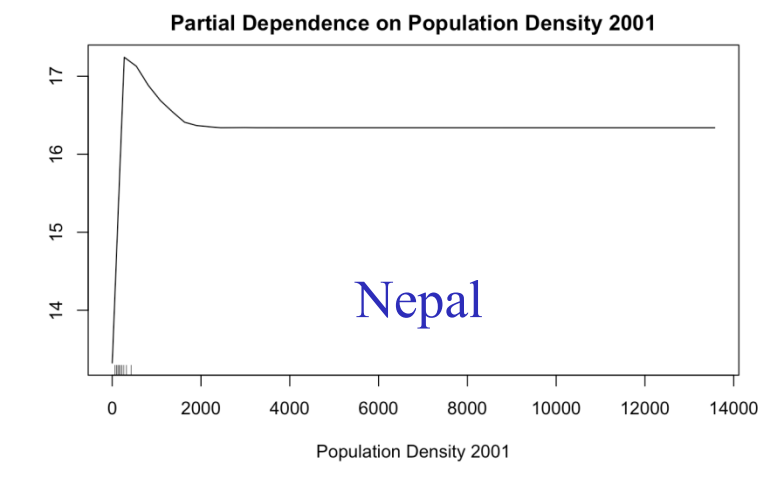


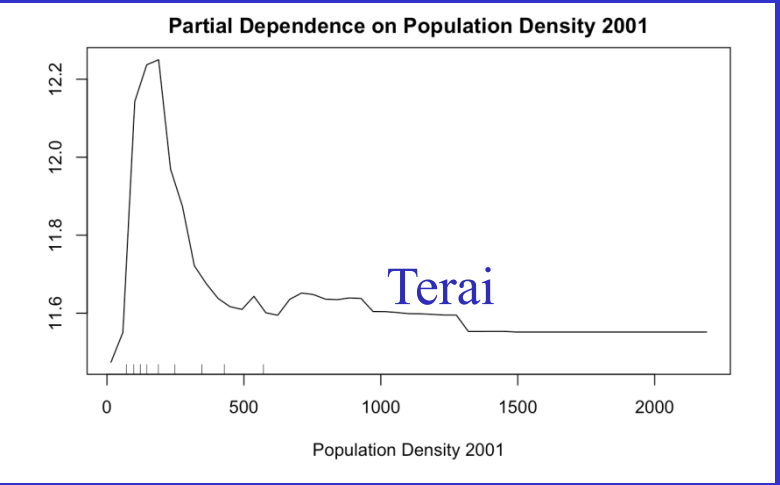


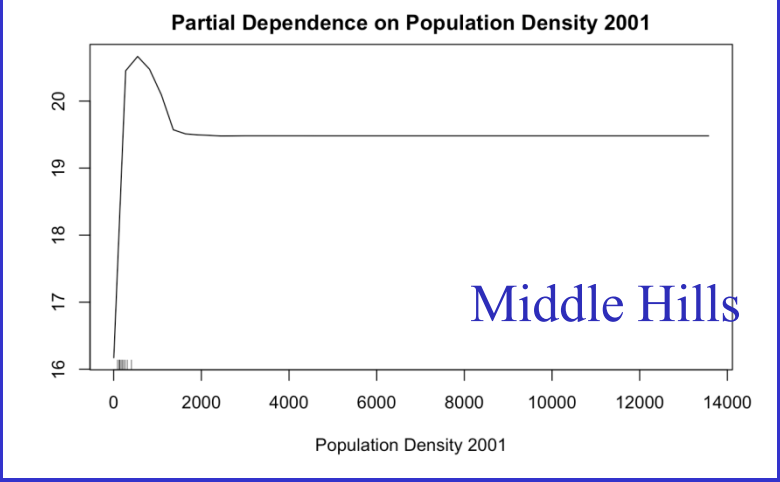


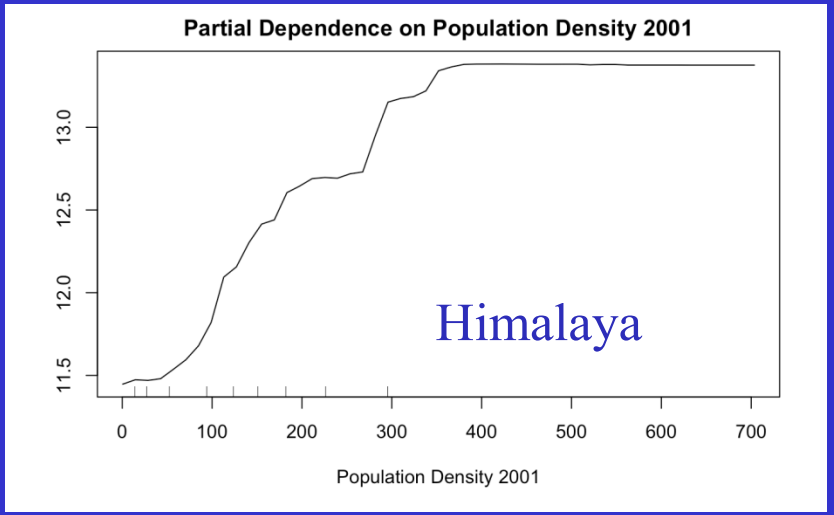


Difference in tree cover between 2016 and 2001 vs. population density

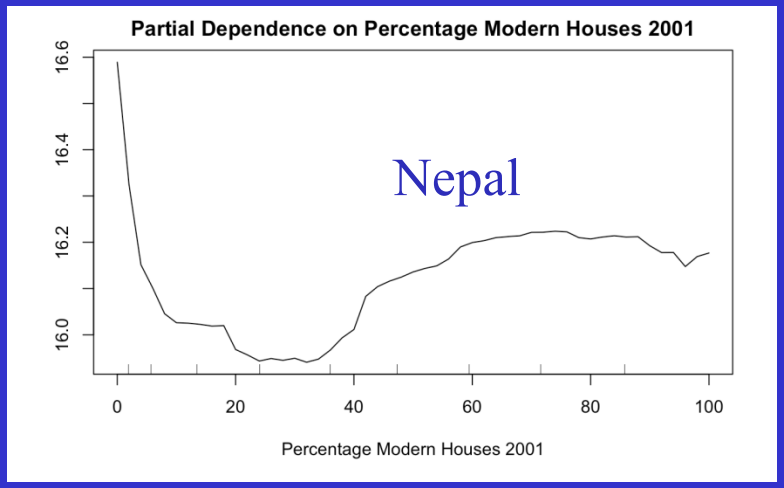


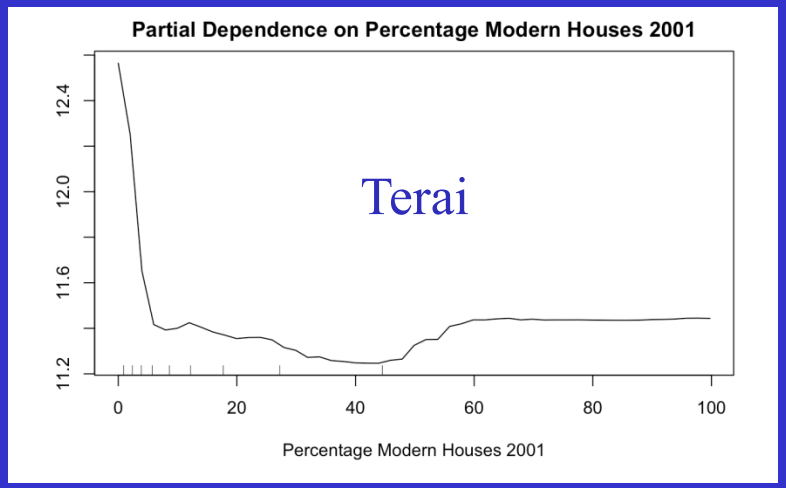


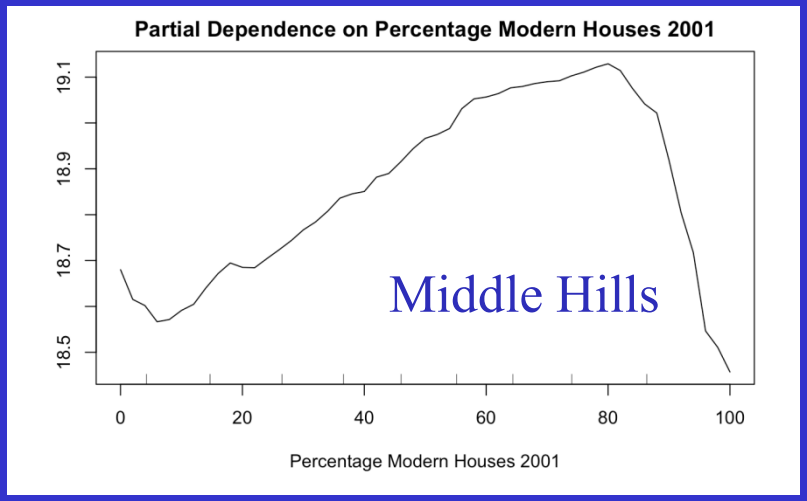


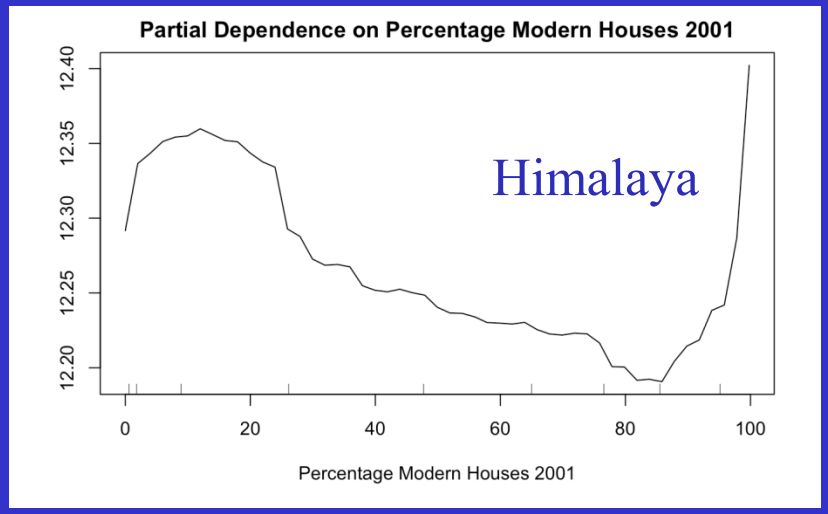


Difference in tree cover between 2016 and 2001 vs. modern houses









Key lessons learnt so far

- VDC level models best developed eco-region wise
- Machine learning models better suited to pry out the non-linear , non-monotonous relationships that have thresholds, tipping points and saturation effects

Pending models

- Growth models (done 2001- 2016)
  - 2001 to 2006
  - 2001 to 2011
  - 2011 to 2016
- Cross-sectional models of TC for 2001 and 2011
- Longitudinal 25-year models
- LandTrend metrics
- All above using ML and RF
- All above at district level
- All above using Hansen FC
- Full set of 19 bioclimatic variables
- Cooking fuel, women in CF, etc

Thank You!