Food Security in Developing Countries: Understanding the Relationships Between Dynamically Changing Social Systems and Natural Resource and Environmental Conditions

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June 21st, 2012
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Acknowledgements

- Committee Members: Dr. Alok Bohara (Chair), Dr. Christine Sauer, Dr. Kristine Grimsrud, Dr. Keshav Bhattari (Central Missouri University)
- University of New Mexico Faculty
- Fellow Graduate Students

Global Poverty and Hunger

Primary Dissertation Objectives

- Analyze economic trade-offs made to ensure long-term food security (*Chapter 2*)
- Understand the role of natural capital and social capital in strengthening household food security (*Chapter 3*)
- Understand international food aid response to ensuring food security in times of emergencies (*Chapter 4*)

Food Security Defined
(Food and Agriculture Organization)

‘Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life’

-World Food Summit 1996, 2002

Trade-offs

-Resources can be consumed now, or in the future
-Maintenance, and investment, in capital in hopes that this will generate future resources

*Food security is higher when food is available today and tomorrow

March 25, 2004 (ISS008-E-19233) - Betsiboka Estuary, Madagascar

Frontier Expansion Hypothesis

- Resource-dependent countries see rapid land expansion in biologically fragile areas typically occupied by the poorest populations.
(Barbier, 2005)

Forest Ecosystem Services
(for food production)

-Protection from flooding and erosion
-Maintenance of soil quality
-Contributions to healthy watersheds

Analysis 1: Optimal conversion of Forest Resources For Increased Agriculture Production (Chapter 2)

- Optimal control model to maximize the value received from agricultural production under the constraint of forest resources
- Calibrated to a case study in Nepal

--Key Findings:

1) Long-term optimal time path of land conversion, to steady state values
2) Variation based on geographic region being considered in Nepal

Nepal: Characteristics (District Level)

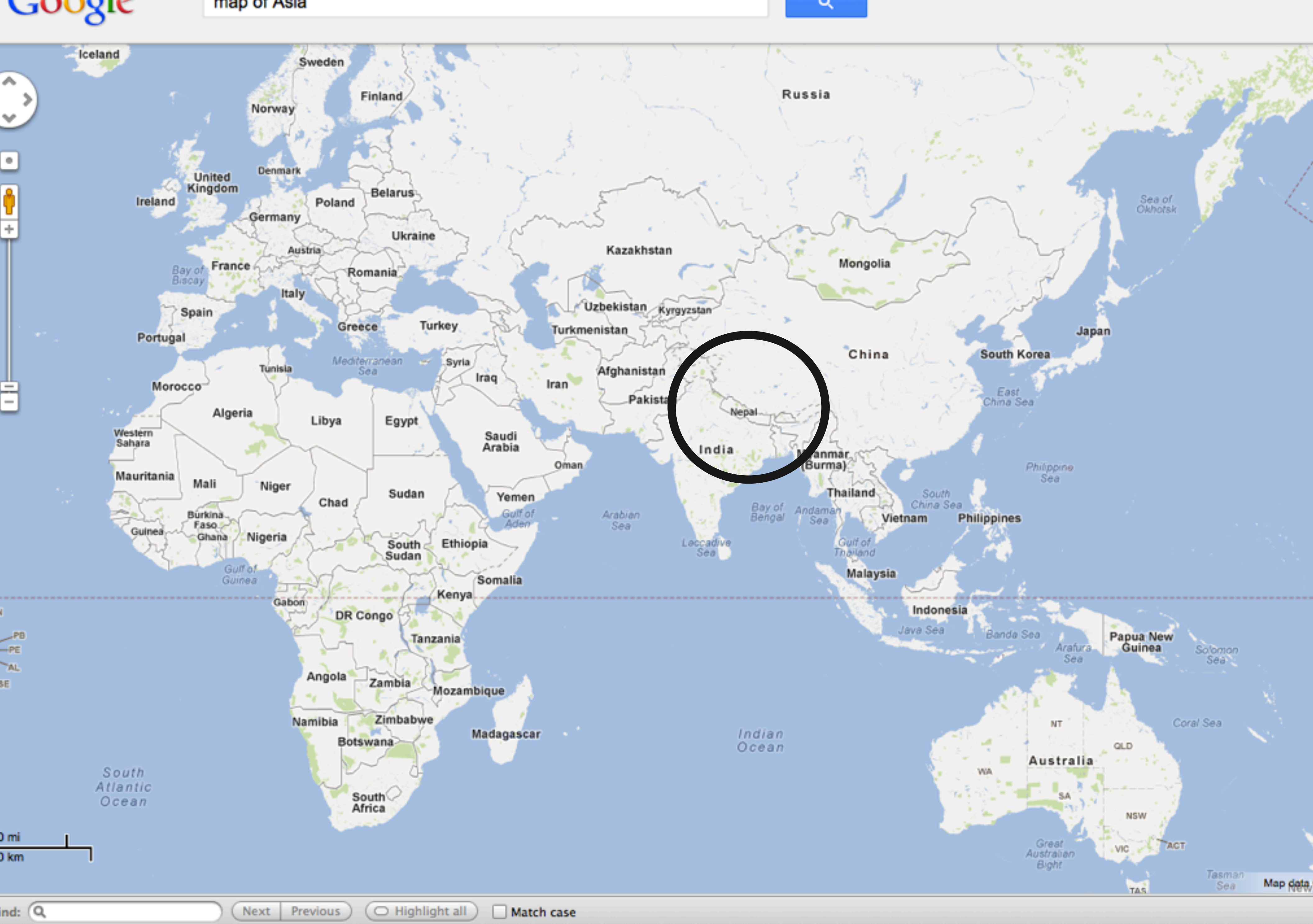
Variable	Mean	Std. Dev.
Forest 2000 (ha)	64,923	53664.02
10 year change	**-34.62%**	0.25
Farmland 2000 (ha)	63,478	41250.58
10 year change	**120.57%**	1.58
Population 2010	319,634	
10 year change	**28.8%**	.192

Data Sources

Raster Imagery (GIS)

Nepal Living Standards Survey
1995-1996, 2003-2004

Calibrate optimal control model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Iceland
Sweden
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Denmark
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Kazakhstan
Mongolia
Italy
Spain
Portugal
Greece
Turkey
Uzbekistan
Kyrgyzstan
Turkmenistan
Japan
China
South Korea
Tunisia
Mediterranean Sea
Syria
Iraq
Iran
Afghanistan
Morocco
Pakista
Nepal
East China Sea
Algeria
Libya
Egypt
Saudi Arabia
Western Sahara
Oman
India
Myanmar (Burma)
Philippine Sea
Mauritania
Mali
Niger
Chad
Sudan
Yemen
Thailand
South China Sea
Gulf of Aden
Arabian Sea
Bay of Bengal
Andaman Sea
Vietnam
Philippines
Burkina Faso
Guinea
Ghana
Nigeria
South Sudan
Ethiopia
Laccadive Sea
Gulf of Thailand
Gulf of Guinea
Somalia
Malaysia
Gabon
Kenya
DR Congo
Indonesia
Tanzania
Java Sea
Banda Sea
Arafura Sea
Papua New Guinea
Solomon Sea
Sea of Okhotsk
Angola
Zambia
Mozambique
Namibia
Zimbabwe
Botswana
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Photos
Kashmir
Hemis National Park
Ngari
Himachal Pradesh
Chandigarh
Nanda Devi Biosphere Reserve
Uttarakhand
Dehradun
Yamunanagar
Saharanpur
Panipat
Haryana
New Delhi
Rewari
Alwar
Jaipur
Aligarh
Agra
Muzaffarnagar
Moradabad
Bareilly
Uttar Pradesh
Farrukhabad
Bhind
Gwalior
Kanpur
Lucknow
Baitadi
Kolti
Mahendranagar
Birpath
Taranga
Dhangadhi
Birendranagar
Nepalganj
Annapurna Conservation Area
Nepal
Bharatpur
Butwal
Hetauda
Kathmandu
Khandbari
Birganj
Gorakhpur
Janakpur
Dharan
Ilam
Damak
Biratnagar
Sikkim
Pankhabari
Bhutan
Tibet
Nagqu
Lhasa
Nyingchi
Shigatse
Shannan
Arunachal Pradesh
Assam
Nalbari
Guwahati
Lanka
Nagaland
Meghalaya
Dibrugarh
Sibsagar
Jorhat
Tuli
Duliajan
Senapati
Karimganj Town
Silchar
Manipur
Mymensingh
Sreemangal
Moulvi Bazar
Bangladesh
Ghorashal
Dhaka
Comilla
Aizawl
Chandpur
Rangamati
Chittagong
Barisal
Khulna
Jessore
Tripura
Monywa
Yesagyo
Patna
Bihar
Begusarai
Dinajpur
Bogra
Naogaon
Rajshahi
Allahabad
Varanasi
Aurangabad
Kota
Jhansi
Palpur-Kuno Wildlife Sanctuary
Bhawani Mandi
Satna
Rewa
Sagar
Damoh
Katni
Hazaribagh
Dhanbad
Asansol
Jharkhand
Ranchi
Purulia
Durgapur
Madhya Pradesh
Ujjain
Dewas
Indore
Hoshangabad
Jabalpur
India
Patna
Kunkuri
Jamshedpur
West Bengal
Kolkata
Kharagpur
Magra Hat
Rourkela
Chhindwara
Chhattisgarh
Bhatapara
Raipur
Bhilai
Khandwa
Achalpur
Nagpur
Gondia
Katapali
Kendujhar-Saranda Range
Baleshwar
Bhadrak
Bolangir
Angul
Jalgaon
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Edit in Google Map Maker
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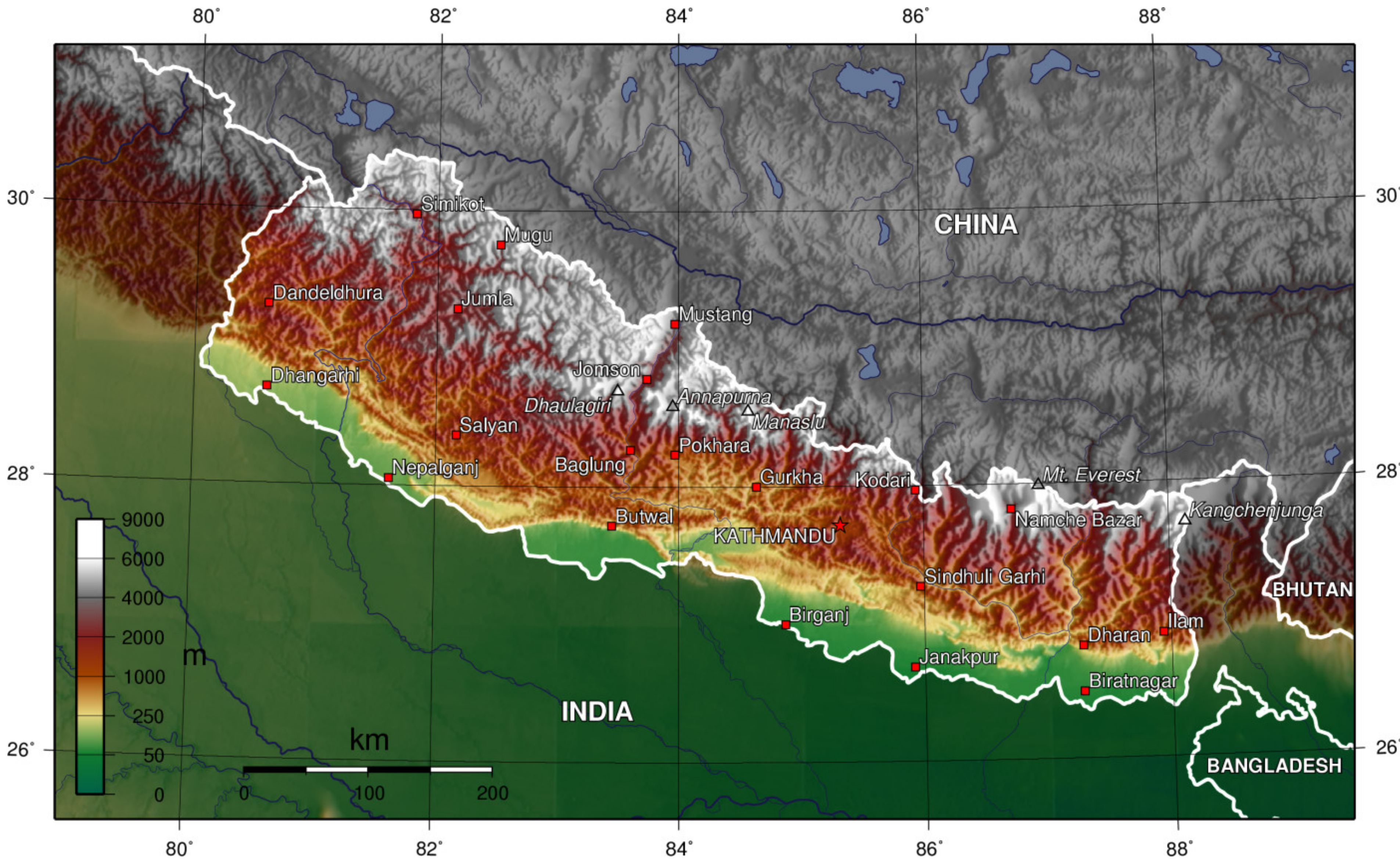
Match case



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Dhaulagiri
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Manaslu
Salyan
Pokhara
Baglung
Nepalganj
Gurkha
Kodari
Mt. Everest
Namche Bazar
Kangchenjunga
Butwal
KATHMANDU
Sindhuli Garhi
Birganj
Ilam
Dharan
Janakpur
Biratnagar
9000
6000
4000
2000
1000
250
50
0
m
km
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100
200

The developed model, maximization of per capita benefits from land under agricultural Production.

$$\underset{a(t)}{Max}\ V = \int_0^{\infty} e^{-rt}[\ B(a_t, P^M(A_t, n_t, \mathbf{X})) - C(a_t, f_t, n_t)]dt$$

s.t.

$$\dot{F}_S = d \cdot f_t \cdot n_t + \boldsymbol{\varpi} \cdot \dot{n} \cdot a_t + s \cdot [L - f_t \cdot n_t - a_t \cdot n_t] + ref$$

$$0 \leq n_t \cdot [f_t + a_t] \leq L$$

With $\quad a_t = \dfrac{A_t}{n_t}, \qquad f_t = \dfrac{F_{St}}{n_t}$

Constrained Present Valued Lagrangian & First Order Conditions

$$\angle = e^{-rt}[B(a,n) - C(a,f,n)] + \boldsymbol{\lambda}(d \cdot f \cdot n + \dot{\boldsymbol{\varpi}}\, n\, a + s[L - f \cdot n - a \cdot n] + ref)$$
$$+\boldsymbol{\mu}(L - f \cdot n - a \cdot n)$$

$$\angle_a : e^{-rt}[B_a - C_a] + \boldsymbol{\lambda}(\dot{\boldsymbol{\varpi}}\, n + s) - \boldsymbol{\mu} \begin{matrix} < \\ = \\ > \end{matrix} 0 \rightarrow \begin{matrix} a = 0 \\ a = \frac{L}{n} - f \\ 0 < a < \frac{L}{n} - f \end{matrix}$$

$$-\angle_f : e^{-rt}[C_f] - \boldsymbol{\lambda}(d + s) + \boldsymbol{\mu} = \dot{\boldsymbol{\lambda}}$$

$$\lim_{t \to \infty} \boldsymbol{\lambda}(t) = 0$$

$$\angle_{\boldsymbol{\mu}} : L - na - nf = \dot{\boldsymbol{\mu}}$$

$\dot{\boldsymbol{\mu}} = 0,\ \boldsymbol{\mu} \geq 0$ $\quad$ $L\text{-}fn\text{-}an \geq 0$ $\quad$ $\boldsymbol{\mu}(L - fn - an) = 0$

Ordinary Differential Equations

$$\dot{a} = \frac{1}{-(B_{aa} - C_{aa})}\left[\begin{array}{l} -r(B_a - C_a) - C_{af}[df - \boldsymbol{\varpi}\dot{n}a - s(\frac{L}{n} - a - f + \frac{ref}{n})] \\ -(\frac{n[B_a - C_a]}{(\boldsymbol{\varpi}\dot{n} + s)})[(\boldsymbol{\varpi}\ddot{n}) - (d+s)(\boldsymbol{\varpi}\dot{n} + s)] - (C_f)(\boldsymbol{\varpi}\dot{n} + s) \end{array}\right]$$

$$\dot{F}_S = df(t)\cdot n + \boldsymbol{\varpi}\dot{n}a(t) + s[L - f(t)\cdot n - a(t)\cdot n] + ref$$

Calibrating the Model

$$P^{m}_{jt} = \underset{(1.214)}{-2.66}\ \mathrm{A}_{j,t} + \underset{(0.151)}{0.373}\ n_{j,t} + \underset{(0.368)}{0.933}\ \mathrm{L}_{j,t} - \underset{(190097.2)}{422536.6}\ mnt_{j}$$
$$- \underset{(169063.4)}{339412.1}\ hills_{j} - \underset{(131344.8)}{372096.6}\ \mathrm{ter}_{j} + \underset{(185097.2)}{365024.1}$$

(*robust s.e.*), *R-squared*=0.2297, *n*=144, *Hausman*=5.92, (P=0.0518)

$$C(a,f,n) = a(6761.8 - 542.0\ a + 11.9\ a^{2}) - f(1625.0 - 361.4\, f)$$
$$- 2230.3\ (a \cdot f) + 0.006\ n$$

(robust s.e.), N=4990, *R-squared*=0.366, *F-test*=249.76

Calibrating the Model (cont.)

10-year forest change (divide coefficients by 10 for the model)

$$\dot{F}_s = \underset{(0.235)}{0.812}\, F_s - \underset{(0.349)}{0.582}\, \dot{n}\, a - \underset{(0.131)}{0.424}\, (L - F_s - A)$$

$$+ \underset{(4391.5)}{9608.9}\, ter + \underset{(4391.6)}{9546.8}\, mnt + \underset{(2575.8)}{8524.2}\, hil$$

(s.e.), N=72, *R-squared (centered)*=0.544; *F-test*=10.29;

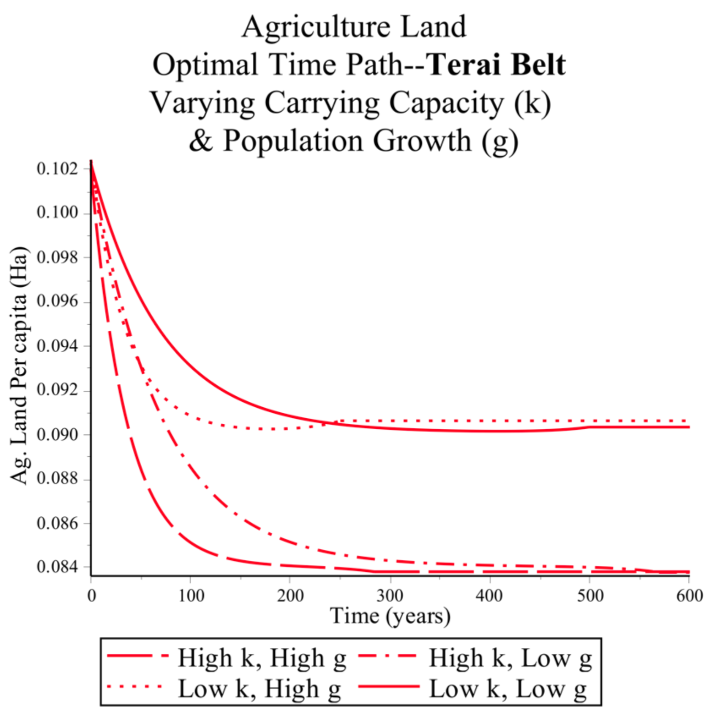
Kleibergen-Paap rk LM statistic (Underidentification test)=17.12 (p=0.000); *Kleibergen-Paap rk Wald F statistic* (Weak identification test)= 59.295 (*Stock-Yogo 10% Critical Value*=19.93); *Hansen J Test for instruments*= 2.145 (chi. sq. p=0.143)

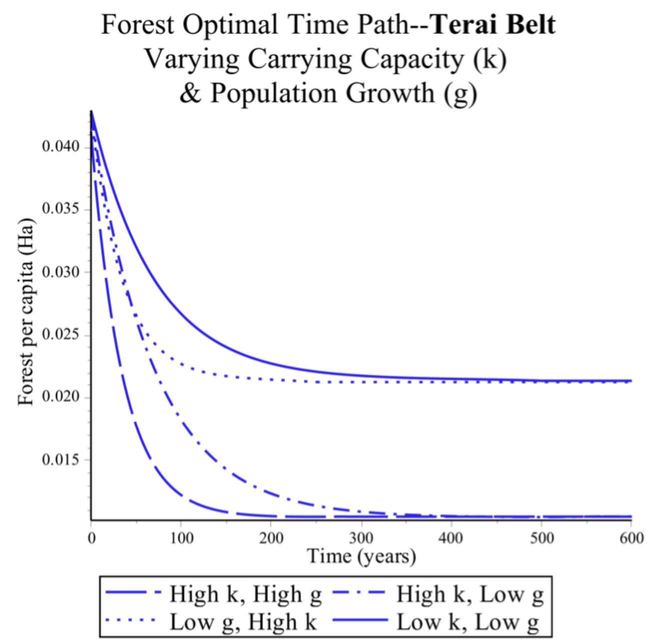
$$\dot{n} = gn\left(1 - \frac{n}{k}\right)$$

Verhulst logistic equation

Chapter 2 Results

Figure 2-3. Optimal time paths, Terai Belt.





High k=200% of current population, Low k=150% of current population

High g=1.8% annual growth rate, Low g=1.4% annual growth rate

Chapter 2 Results (cont.—g=1.4%, k=150%)

Region	2000 *f*	2000 *a*	Optimal Starting Values (f)	Optimal Starting Values (a)
Terai	.04	.15	.042	.102
Hills	.26	.19	.14	.172
Mountain	1.14	.73	.656	.435

Chapter 2 Key Conclusions

- Long-term value of agriculture production relies on maintenance of stocks of primary forest
- Optimal forest levels slightly above 2000 levels for Terai belt
- Direct benefits of forest stock may indicate the need for further maintain forest stocks

An issue of inadequate food supply?

<u>Amartya Sen:</u> Food Security: A question of vulnerability and access to food.

Poverty and Famines: An Essay on Entitlement (1981)

Bengali famine of 1943

Household determinants of food security in Nepal (Chapter 3)

Key Questions

-What is the role of natural capital, social capital, and coping mechanisms in determining household food security in Nepal?

Key Impacts on Food Security:

-Time to collect clean water and % of forest cover

-Caste status, presence of active community groups

-Access to food aid, loans, and remittances

Case Study: Nepal

http://www.flickr.com/photos/cimmyt/6195475730/sizes/o/in/photostream/

Maximize Utility to Give an Optimal Level of Consumption

$$C_i^{H,M} = C(p_i^{H,M},\ w,\ A, K_i, N, D_i^H)$$

Generalized Econometric Model

$$FS_i = \beta_C + \beta_{NC} NATCAP + \beta_{SC} SOCCAP + \beta_{CO} COPING$$
$$+ \beta_V VIOL + \beta_L LOCAT + \beta_E SOCIOEC + \varepsilon_i$$

Data Sources Combined for the Analysis

Raster Imagery (GIS)

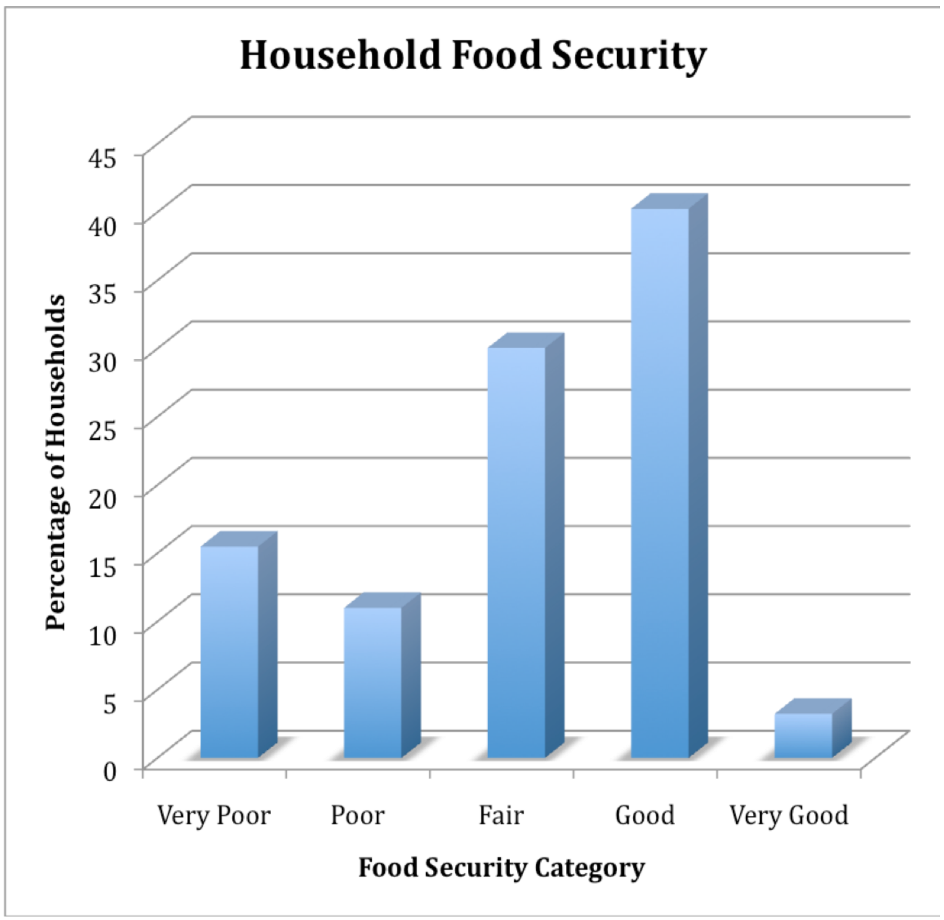
Nepal Living Standards Survey 1995-1996, 2003-2004 (Social Capital Data)

Nepal Conflict Data

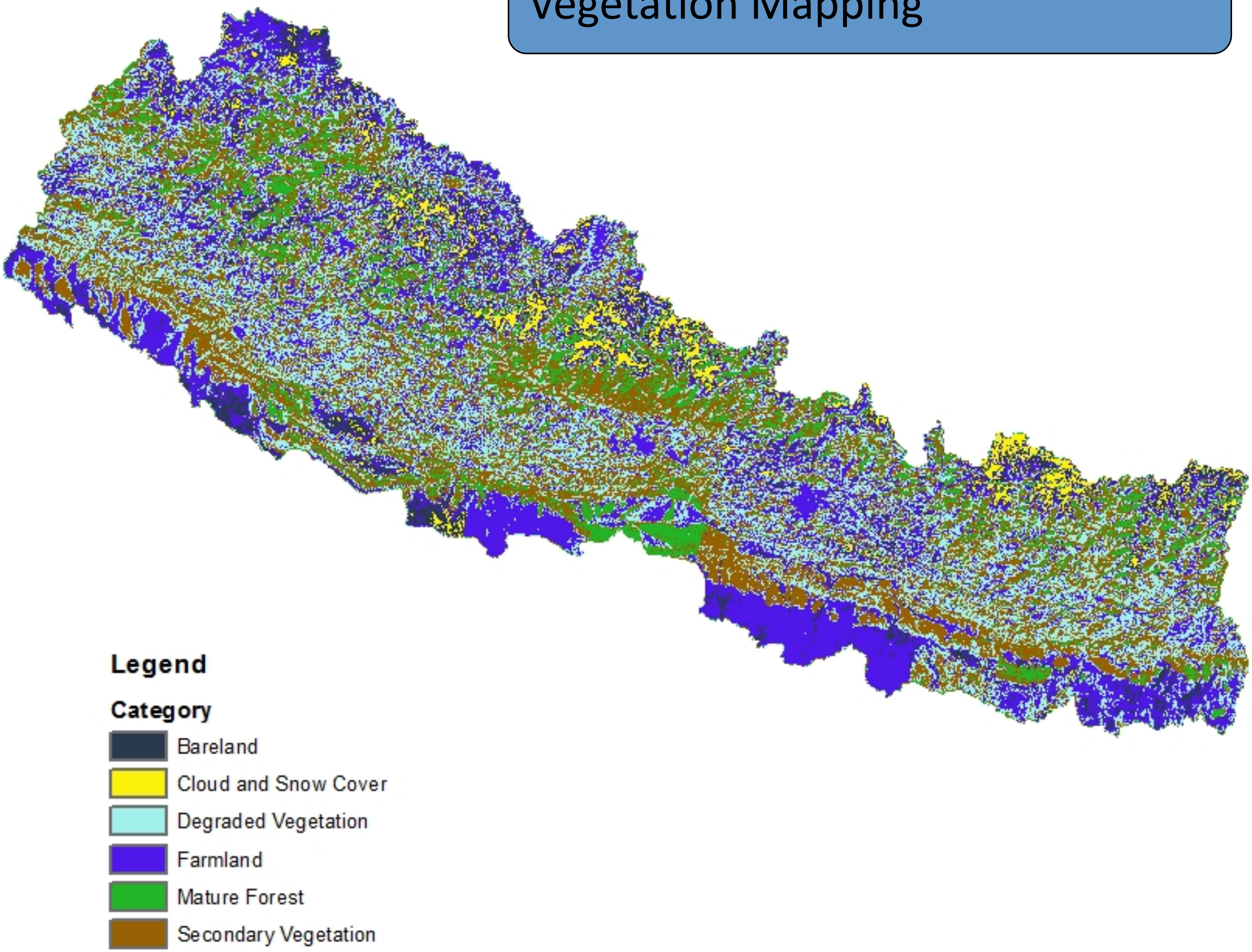
Food Security HH Survey

Food Security Measure---Food Index

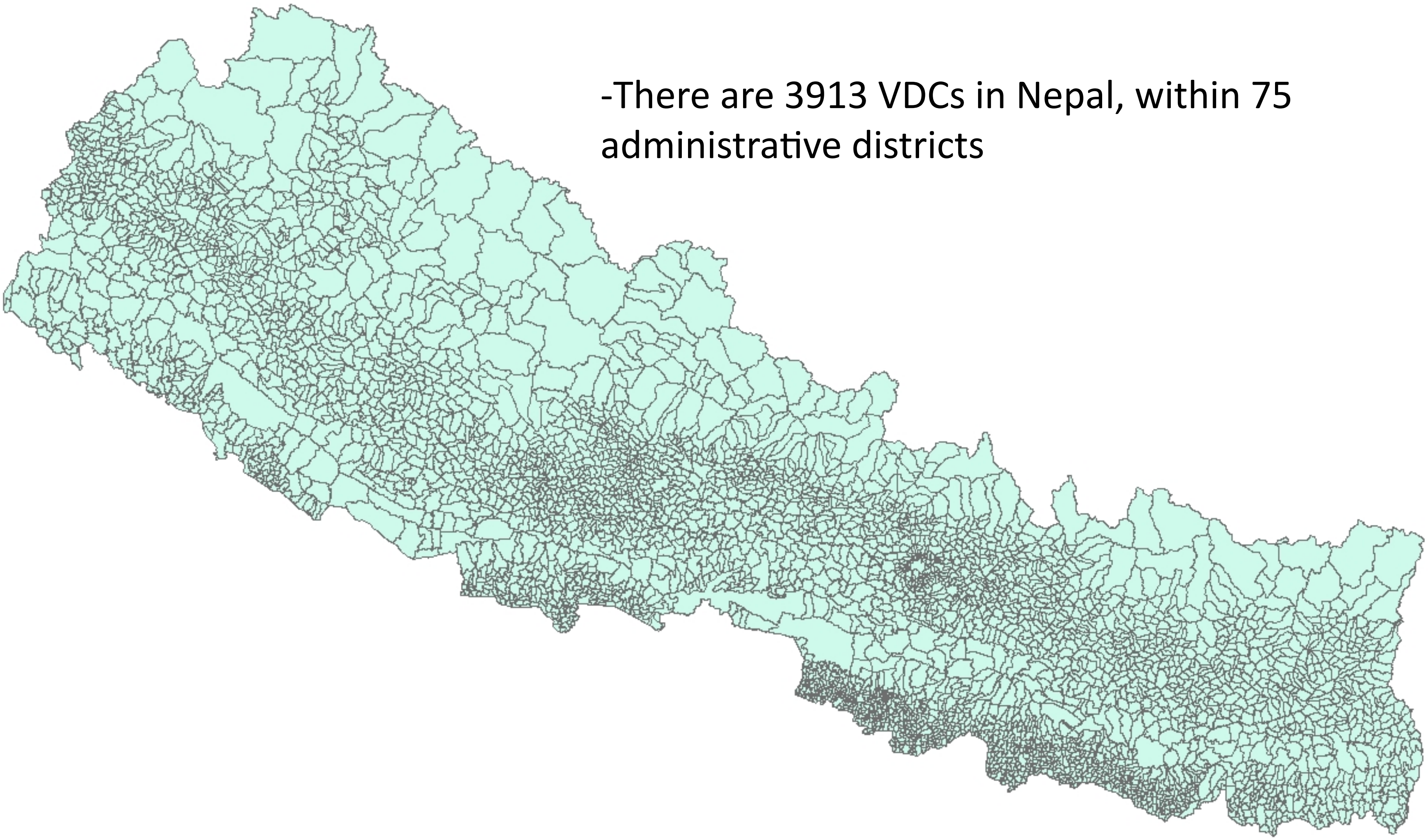
$$FOODINDX = staple \;\; starches * .2 + pulses * .3 + meat / fish / eggs * .4 + milk * .4$$
$$+ fruit * .1 + vegetables * .1 + oil * .05 + sugar * .05$$



Vegetation Mapping

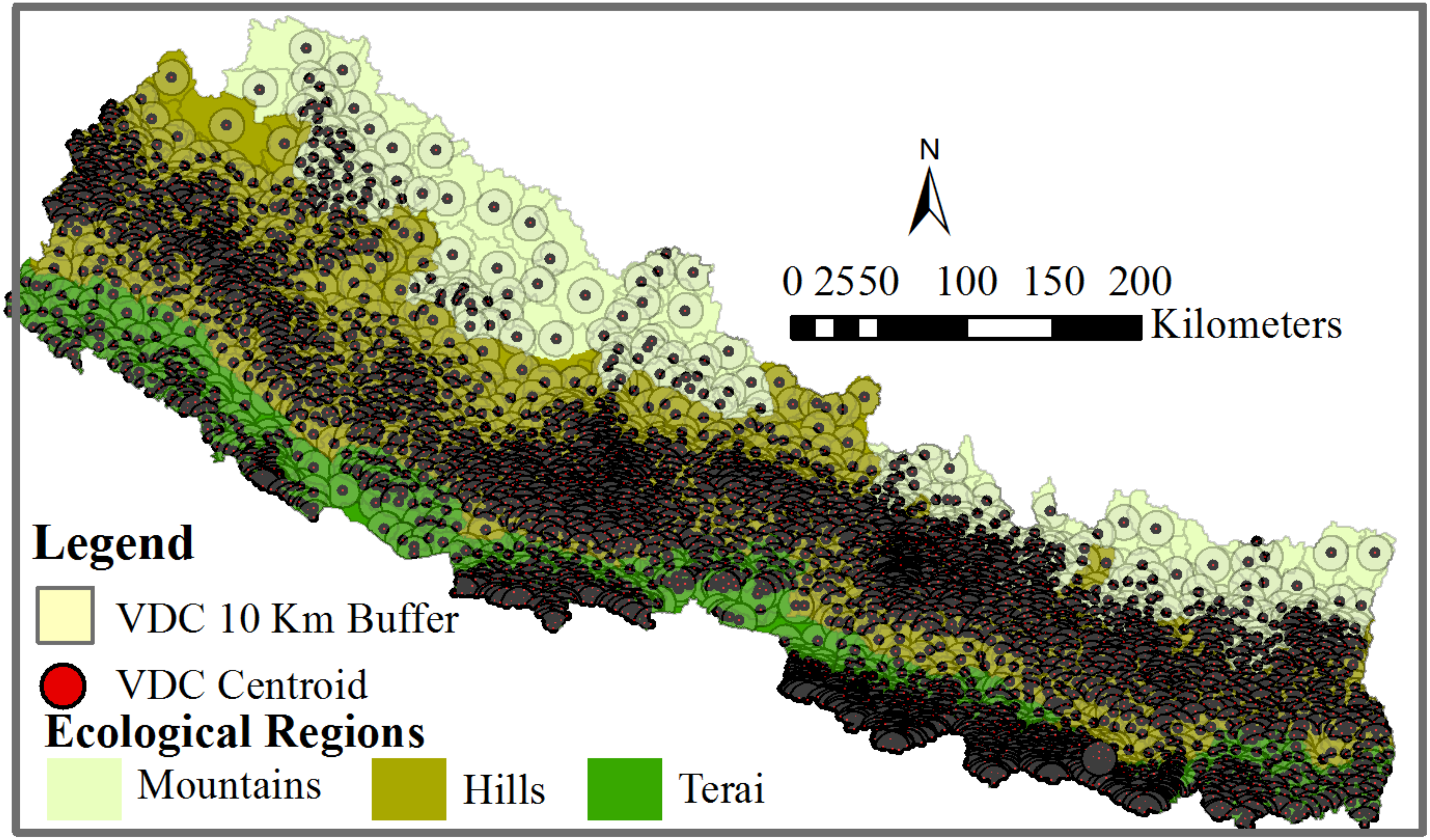


Nepal Village Development Committees (VDCs)



-There are 3913 VDCs in Nepal, within 75 administrative districts

Buffers around each of VDCs (10, 20, 30 km buffers)



Social Capital Index

$$SCI_{md} = \sum_{n=1}^{4} \frac{X_{nd} - \min(X_n)}{\max(X_n) - \min(X_n)}$$

-Where X is a characteristic of the user group being considered

Social Capital—Caste Membership

- Marginalized castes: Dalit, Janjati, and others
- Privileged castes: Brahmin or Chhetri

Hypothesis: Membership in marginalized castes will make households more vulnerable to food insecurity.

Primary Results

Explanatory Variables (Foodindx Dep. Variable)	Model II	Model III	Model IV	Model V
Natural Capital				
WATDIS	-0.466*	-0.410*	-0.398*	-0.441*
VEG	0.036***	0.044***	0.043***	0.039***
Social Capital				
$CLASS^{DALIT}$		-0.380*	-0.327	-0.349
$CLASS^{JANJATI}$		-0.905***	-0.872***	-0.893***
$CLASS^{OTHER}$		-0.548*	-0.543*	-0.492
SCI^{ALL}		0.098***	0.096***	0.097***
Coping Mechanisms				
$COPE^{REMIT}$			0.248*	0.261*
$COPE^{CREDIT}$			0.272**	0.264**
$COPE^{FOODAID}$			0.223*	0.201*
VIOL				-0.010**
AIC	6773.7	6790.9	6769.4	6719.8

(Significance: * 10%, ** 5%, ***1%), n=1674, robust standard errors (not included for purposes of brevity)

Endogeneity Tests

Explanatory Variables	Model II	Model III	Model iV	Model V
Kleibergen-Paap rk	77.347***	73.979***	76.503***	82.616***
Hansen J-stat	3.856	5.125	4.412	2.224
Kleibergen-Paap Wald	30.909[a]	28.523[a]	29.504[a]	32.412[a]
End. (χ^2) VEG^{VDC}	8.433***	14.508***	15.376***	15.523***
End. (χ^2) SCI^{ALL}		0.464		
End. (χ^2) *FOODAID*			1.006	
End. (χ^2) *VIOL*				1.857

Spatial Modeling

$$FS_i = \mathbf{X}_i\boldsymbol{\beta} + \mathbf{Y}_j\boldsymbol{\lambda} + \mathbf{WY}_{jn}\boldsymbol{\lambda} + z_i \qquad i = 1,..N;\ j = 1,...,J$$

Spatial Decay Function

$$W = \sum_{d=0}^{D}\left(\frac{\exp^{\boldsymbol{\kappa}}}{1+\exp^{\boldsymbol{\kappa}}}\right)^{d}$$

Dependent Variable *FOODINDX*	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Non-Linear Model 5**
VEG^{VDC}	0.039***				
VEG^{10B}		0.010*			
VEG^{20B}			0.022***		
VEG^{30B}				0.022**	
λ10,20,30					0.499***
K					-1.035
ETA					0.035***
N	1674	1674	1674	1674	1674
AIC	6719.8	6495.1	6484.0	6489.9	6470.0

Dependent Variable *FOODINDX*	**Model 1b**	**Model 2b**	**Model 3b**	**Model 4b**	**Model 5b**
SCI^{AGRIC}	0.441**				
SCI^{WATER}		0.267***			
SCI^{FOR}			0.784**		
SCI^{WOMEN}				-0.333	
SCI^{ALL}					0.096***
N	1674	1674	1674	1674	1674
AIC	6542.62	6522.67	6659.4	6596.52	6525.09

Chapter 3 Key Conclusions

•Vegetation quantity positively impacts food security, not only in the local area but in areas surrounding the VDC

•Strategies for regional management important, as conservation work by one village will benefit villages in the area---Free Rider Problem

•Promotion of user groups has the potential to boost food security
•Ensuring safety nets for marginalized groups is necessary (e.g. micro loans and development food aid)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HERCULES


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Dynamic Analysis of Food Aid (Chapter 4)

•Analyzing the response of food aid in times of natural disasters
---using dynamic GMM model

Key findings:

1) Emergency food aid increases with rapid onset natural disasters and gradual disasters with a lag
1) Emergency food aid responds to presence of displaced people

GMM Approach

$$\min_{\hat{\beta}} \left[\frac{1}{N} \sum_{i=1}^{N} \mathbf{m}(y_i, \mathbf{x}_i, \mathbf{z}_i, \hat{\beta}) \right]' \cdot W \cdot \left[\frac{1}{N} \sum_{i=1}^{N} \mathbf{m}(y_i, \mathbf{x}_i, \mathbf{z}_i, \hat{\beta}) \right]$$

$$\hat{\beta}_{GMM} = [(\frac{1}{N}\sum_{i=1}^{N} \mathbf{z}_i \mathbf{x}_i') \cdot W \cdot \frac{1}{N}\sum_{i=1}^{N} \mathbf{z}_i' \mathbf{x}_i]^{-1} \cdot (\frac{1}{N}\sum_{i=1}^{N} \mathbf{z}_i \mathbf{x}_i') \cdot W \cdot (\frac{1}{N}\sum_{i=1}^{N} \mathbf{z}_i' y_i)$$

If we set $W = \mathbf{z}_i' \mathbf{z}_i$, then $\hat{\beta}_{GMM} = \hat{\beta}_{2SLS}$

Econometric Model

$$y_{i,t} = y_{i,t-l}\alpha + \boldsymbol{x}_{\boldsymbol{i},t}\beta + u_i + v_{i,t}$$

Data Sources

EM-DAT
The International Disaster Database
Centre for Research on the Epidemiology of Disasters - CRED

THE WORLD BANK
Working for a World Free of Poverty

INSCR
Integrated Network for Societal Conflict Research

WFP
United Nations
World Food Programme

FAIS Monitoring System

Chapter 4 Results

Dynamic Panel Analysis (GMM System): Low and Middle Income Countries-Per Capita Analysis					
Dep. (ln)AIDCAP	Model I	Model II	Model III	Model IV	Model V
(ln)AIDP $_{t-1}$	0.570***	0.533***	0.518***	0.484***	0.486***
(ln)AIDP $_{t-2}$		0.090	0.125***	0.112***	0.103***
(ln)FOODP	-0.378*	-0.418***	-0.363***	-0.303*	-0.337*
(ln)SUDISP	0.030*	0.033**	0.037***	0.035***	
(ln)SUDISP $_{t-1}$			0.004	0.008	
(ln)GRADISP	0.008	0.014	0.024	0.013	
(ln)GRADISP $_{t-1}$			0.061***	0.059***	
(ln)TOTDISP					0.030**
(ln)TOTDISP $_{t-1}$					0.038***
(ln)DISPP				0.984***	0.957***
N	2196	2110	2110	1989	1989
Countries	114	114	114	113	113

	Model I	Model II	Model III	Model IV	Model V
Instruments	81	80	85	85	75
Arellano–Bond AR(2)	0.058	0.795	0.951	0.736	0.617
Hansen Overid. test	0.193	0.292	0.546	0.689	0.424
Difference-In-Hansen (p-values)					
All System Instruments	0.863	0.959	0.243	0.374	0.191
Dep. Variable Instruments	0.580	0.949	0.801	0.869	0.846
Number of Instrument Lags	10	10	10	10	10

Chapter 4 Conclusions

- Important result to show the relationship of emergency food aid with gradual onset disasters

- Media plays an important role in communicating the need to respond during disasters

- Early monitoring systems---educate international community, and the public, as early as possible

Final Remarks

•World has made progress towards addressing poverty

•Reality of hunger remains—response crosses political ideology

•Global climate change and population growth exacerbate food security concerns

•Research helps to identify those key natural systems and social systems that must be invested in to strengthen food security

•Research used to communicate these important issues to people living in developed countries

Bonus Slides

Region	2000 *f*	2000 *a*	Optimal Starting Values (f)	Optimal Starting Values (a)
Terai	.04	.15	.042	.102
Hills	.26	.19	.14	.172
Mountain	1.14	.73	.656	.435

Table 4-1. Summary Statistics

			Low and Middle Income Countries		*All Countries*	
Variable	Definition	Source	Mean	S.d.	Mean	S.d.
(ln)AIDP	Emergency food aide (log of grain equivalent metric tons per 10,000 people)	United Nations World Food Program, Food Aid Information System, http://www.wfp.org/fais/ (January 12, 2012)	1.3237	1.6641	1.0190	1.56
(ln)POP	Population (log of people in tens of thousands)	The World Bank, World Development Indicators http://data.worldbank.org/indicator (January 12, 2012)	16.2102	1.5006	16.2195	1.47
(ln)TRADE	GDP originating from trade (log of % of GDP)	Ibid.	4.2247	0.5070	4.2398	0.49
(ln)DEMOC	POLITY Democracy Index (log of transformed democracy index, 0 to 3.04, where 3.04 is most democratic)	Center for Systemic Peace, Polity IV Project, http://www.systemicpeace.org/polity/polity4.htm (January 12, 2012)	2.3596	0.6779	2.4681	0.70
(ln)GDPP	GDP (log of 2000 USD per 10,000 people)	Ibid.	6.7087	1.0815	7.3958	1.58
(ln)FOODP	Dry grain production levels (log of metric tons per 10,000 people)	Ibid.	7.0812	1.3877	7.3005	1.44
(ln)SUDISP	Rapid onset natural disasters (floods, storms, earthquakes, volcanoes, etc.) (log of people affected)	Centre for Research on the Epidemiology of Disasters, The International Disaster Database, http://www.emdat.be/ (January 12, 2012)	1.7542	2.2138	1.4681	2.07
ln)GRADISP	Natural disasters with a slower onset (droughts	Ibid.	0.8059	1.8761	0.6344	1.69