

Economic Valuation of Storm Protection Function: A case Study of Mangrove Forest of Orissa and 1999 Super Cyclone.

Saudamini Das
Institute of Economic Growth, Delhi.

Supervisor: - Prof. Kanchan Chopra.

Sponsoring Organization: - South Asian Network for Development and Environmental Economics (SANDEE).

Advisor at SANDEE: - Prof. Jeffery R. Vincent.

BACK GROUND OF THE STUDY

- Super Cyclone of Oct, 1999 in state of Orissa of India.
- Tremendous loss of lives and properties.
- Wide reporting in national and international press that mangrove forest areas witnessed little damage compared to other areas.

Sequence of the presentation

- Introduce the objectives of the study.
- Describe the study area and its special physical features.
- Describe the methodology used to value the storm protection service.
- Present some estimates and predictions (**preliminary**) for the human casualty function.

Broad Aim of the Research

- Quantifying the Protection Provided by the Mangrove Forest from the **Wind Damages and Storm Surge Damages** due to the Super Cyclone of October 29, 1999.
- Protection from only **3 types** of damages i.e **Loss of Human life, Livestock and Damages to Residential structures** will be quantified.

Specific Objectives of Research

Primary: -

- Calculating the Storm Protection Values of **Mangrove Forest** in terms of Reducing human death, residential house damages and loss of livestock.

Subsidiary: -

- Verifying Whether **Mangrove forests** provide better protection from cyclones than the non-mangrove forest, particularly, the **Casuarinas trees**.
- Verifying whether **non-mangrove Indigenous Forests (Native Forests)** are better cyclone buffers than the **Casuarinas Trees**.

ORISSA STATE (cyclone affected area)



Study Area for human casualties function

Kendrapada District

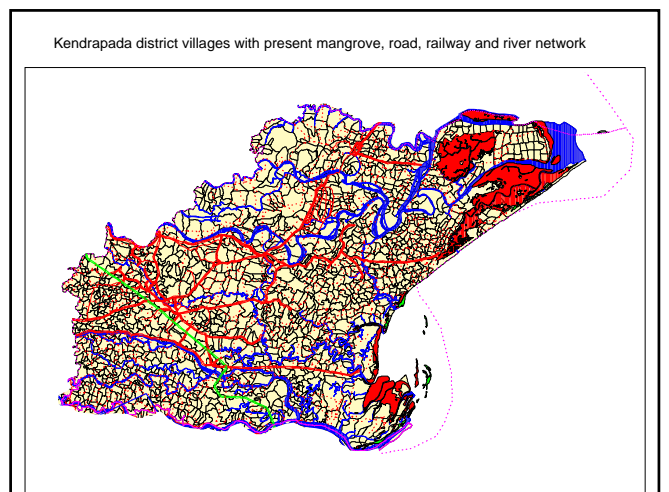
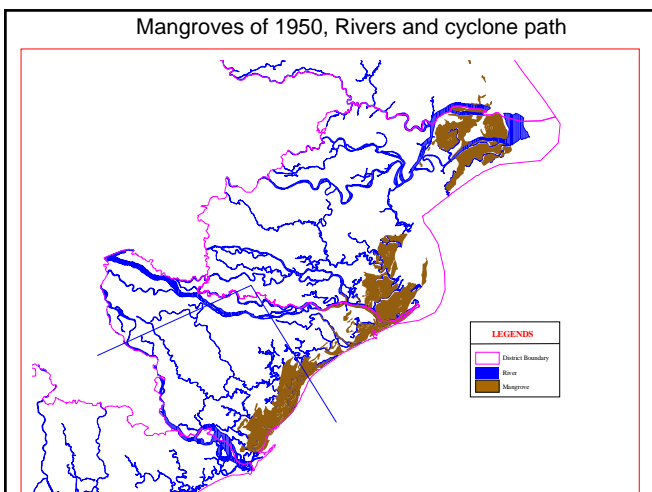
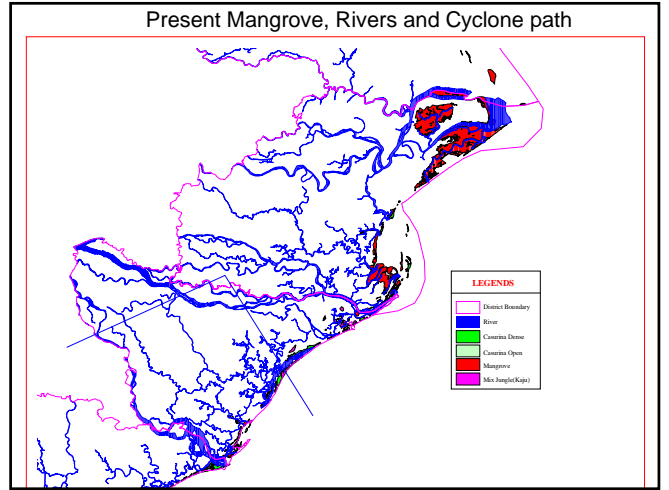
Location: - (86° 14' to 87° 3' east & 20° 21' to 20° 47' north)

Why Kendrapada?

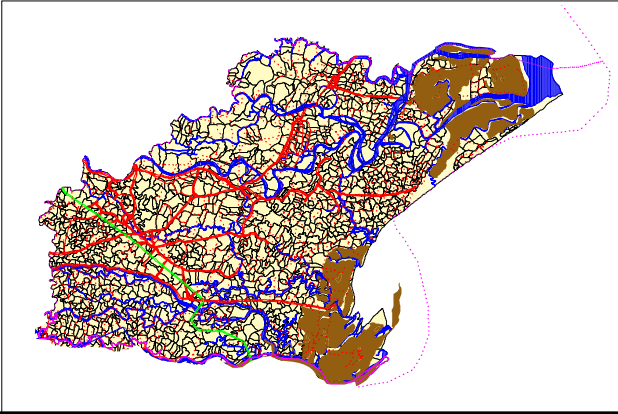
- Entire district lies to the north of cyclone landfall.
- Wind direction was uniform (sea to land) throughout the affected days.
- Has only mangrove forest on the coast line.
- Mangroves are found in different non-uniform discontinuous patches.

District Kendrapada

BLOCKS/TAHASILS	POPULATION	HOUSEHOLD	VILLAGES	% OF BPL	POP DENSITY	DEATH IN CYCLONE
AUL	134158	19421	118	51	598	12
DERABIS	135571	18902	172	67	740	67
GARADPUR	96978	15044	133	63	680	44
KENDRAPADA	131454	19178	131	42	538	35
MAHAKALPADA	191663	25996	190	51	408	188
MARSAGHAI	116508	17666	106	60	739	38
PATTAMUNDAI	147196	20822	138	59	577	20
RAJKANIKA	128947	18634	156	59	489	00
RAJNAGAR	145260	16715	245	66	422	46



Kendrapada district with 1950 mangroves, road, railway and river network



Research Methodology

Estimate the damage function and calculate the protection value.

$$D_i = f(P_i, V_i, W_i, S_i) \quad (1)$$

Where D_i is the damage suffered in the i th village,
 P_i is property at risk (depend on the type of damage),
 V_i is the approximate measure of wind velocity in the i th village,
 W_i is the level of flooding due to storm surge in the i th village and
 S_i is the group of socio-economic factors that influence the extent of damage and the adaptive behavior of people.

Wind Velocity function

Assumption 1: - Wind stress is proportional to square of wind velocity.

Assumption 2: - Wind velocity decreases exponentially both with distance inland (maximum wind) and with distance away from eye-wall region.

Assumption 3: - Rate of decline of wind speed gets accentuated with the presence of physical barriers like mangroves or other forests on the wind path.

$$V_i = f(LW, dcypath, dcoast, mangrove, casuarinas, dmangrove, dcasuarinas) \quad (2)$$

where

V_i is wind velocity at the i th village,

LW is landfall wind velocity (only one value i.e., 256 KMPH in the present case).

$dcypath$ is distance of a village from cyclone path (eye-wall is never clearly defined),

$dcoast$ is distance of a village from coast line,

$mangrove$ is the width of mangrove forest on dcoast,

$dmangrove$ is distance of the village from mangrove forest boundary and

similarly, the $casuarinas$ and $dcasuarinas$.

Storm Surge Velocity function

Assumption 1: - Surge Velocity at any Village will depend on the level of Sea Elevation (height of water) at the coastal point lying at a minimum distance from the village.

Assumption 2: - Level of flooding and velocity of surge water goes down exponentially with distance inland and presence of barriers at the coast.

Assumption 3: -Sea Elevation at different places on the coast doesn't depend only on the wind velocity at those places, but also on other factors like:

contd.....

Contd...

- (1) The direction of the place vis-à-vis the landfall,
- (2) The bathymetry of the place,
- (3) The radius of the maximum wind,
- (4) The angle that cyclone path forms with the coast line,
- (5) Pressure drop
- (6) Speed of cyclone,
- (7) Density of sea water,
- (8) Period of astronomical tide etc.

Assumption 4: -Simulated Surge envelop provided by the meteorologists after taking into account the above mentioned factors is a near approximate measure of the sea elevation.

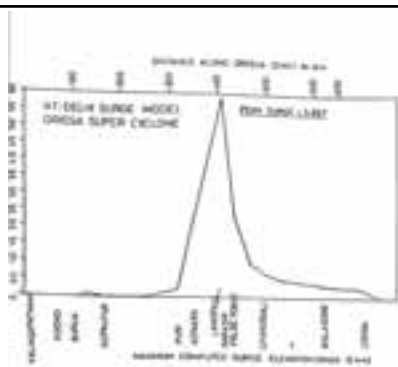


Fig. 6: Surge envelope (100-year return period) for a 100 km radius of maximum wind.

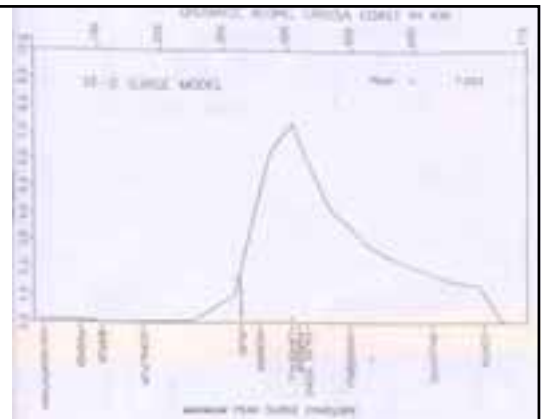


Fig. 7: Surge envelope (100-year return period) for a 100 km radius of maximum wind.

$$W_i = w(\text{surge, dcoast, mangrove, casuarinas, dmangrove, dcasuarinas, elevation, dmajriver, dminriver}) \quad (3)$$

Where, **W_i** is the velocity of water (that is proportional to level of flooding) in a village due to surge,

surge is the level of sea elevation (in meter) at the coast facing the village,

elevation is the height of the village compared to sea,

dmajriver is the distance of the village from a major river,

dminriver is the distance from a minor river and others have already been explained.

Socio Economic Factors

$$S_i = s(\text{pop99, literate, schedulecaste, worker, nonworker, droad, roadummy}) \quad (4)$$

pop99 is total population of a place in 1999, **literate** is the percentage of literate people (proxy for adaptive behavior to cyclone warning), **schedulecaste** is the percentage of scheduled caste and scheduled tribes in total population (economically most backward),

worker is the percentage of workers (earning members) in total population, **nonworker** is the percentage of dependants (not exposed to cyclone) in total population,

droad is minimum distance of the village from state highway (better scope to prosper) and

roadummy is a dummy variable for the presence of village road (easy connection to metal road).

Estimating Equation (putting eq2, 3 and 4 in eq1)

$$D_i = f(\text{LW, dcoast, dcypath, mangrove, casuarinas, dmangrove, dcasuarinas, surge, elevation, dmajriver, dminriver, tpop, literate, schedulecaste, worker, nonworker, droad, roadummy}) \quad (5)$$

where **D_i** is the damage suffered in the *i*th village (**no of human casualties, no of houses damaged or no of different types of livestock lost**) and the explanatory variables have already been explained.

Non-linear regression estimates (tobit, poisson and nonlinear least squares) will be used to estimate the damage equation in accordance with the **meteorological and fluid dynamics hypothesis**.

Data Sources

- **Emergency offices and Tahasildar offices of the Government of Orissa** (Different types of damages).
- **Digitized village map, coastal forest map, road network and river network map and GIS ARCVIEW software** (different distances and width of forest) .
- **P.W.D. dept, Govt of Orissa** (elevation of villages; could get only 44 observations for 900 villages. Hence replaced elevation by topography dummy).
- **Meteorology Dept of Govt of India** (surge or the surge envelop).

Human Casualties Equation

$sucydeath_i = f(LW, dcoast, dcypath, mangrove, casuarinas, dmangrove, dcasuarinas, surge, elevation, dmajriver, dminriver, pop99, literate, schedulecaste, worker, nonworker, droad, roadummy)$

$sucydeath_i$ is no of human death in a village during cyclone.

Variables dropped: - **LW** (one observation), **casuarinas** and **dcasuarinas** (very limited presence), **dmangrove** (captured same effect as dcoast) **elevation** (few observations).

Additional variables included: -

topodummy (based on 1950 mangrove and present mangrove to capture vulnerability; = 1 if has mangrove today or in 1950, = 0 otherwise). **block dummies** (efficiency of local administration) and **percentage of different categories of workers**

This equation has been estimated over four different areas to see the robustness of the results.

Area A: - Mahakalpada and Rajnagar block of Kendrapada (428 villages).

Area B: - Mahakalpada and Rajnagar blocks without the 32 villages that were inhabited in between 1991 and 2001 census (396 villages).

Area C: - Makakalpada and Rajnagar blocks of Kendrapada and coastal villages of Chandbali block of Bhadrakh district (these villages are immediately after the mangrove forest) (513 villages).

Area D: - Mahakalpada, Rajnagar, Rajkanika, Aul and Patamundai blocks of Kendrapada district and Chandbali block of Bhadrakh district (898 villages).

Summary statistics- Area A (death-234)

variables	obs	mean	Std.dev	min	max
Sucydeath	428	0.54	1.78	0	21
B4	428	0.58	0.49	0	1
B5	428	0.41	0.49	0	1
Topodummy	428	0.49	0.50	0	1
dcypath	428	40.58	17.71	7.4	72.82
4.7Surge	428	1.54	1.28	0.7	4.7
Dcoast	428	9.37	5.68	0.3	22.49
mangrove	428	1	2.14	0	10
dmajriver	428	1.9	1.77	0.05	9.21
Dminriver	428	2.63	2.21	0.08	11.82
Droad	428	3.61	2.75	0.1	18.17
Roadummy	428	0.60	0.49	0	1
Pop99	428	745.28	767.28	2	60.98
Literate	428	0.56	0.13	0	1
Schedulecaste	428	0.12	0.17	0	1
Worker	428	0.26	0.09	0	1
Htworker	428	0.002	0.007	0	0.078
Otworker	428	0.04	0.07	0	1
nonworker	428	0.72	0.53	0	0.8

Summary statistics- Area B (death =234)

variables	obs	mean	Std.dev	min	max
Sucydeath	396	0.57	1.77	0	21
B4	396	0.55	0.49	0	1
B5	396	0.44	0.49	0	1
Topodummy	396	0.48	0.50	0	1
dcypath	396	39.58	17.64	7.4	72.82
4.7Surge	396	1.59	1.26	0.7	4.7
Dcoast	396	9.57	5.71	0.34	22.49
mangrove	396	0.93	2.04	0	10
dmajriver	396	1.9	1.77	0.05	9.21
Dminriver	396	2.59	2.17	0.08	11.82
Droad	396	3.46	2.54	0.1	13.55
Roadummy	396	0.60	0.49	0	1
Pop99	396	778.18	780.36	6	60.98
Literate	396	0.56	0.12	0	1
Schedulecaste	396	0.11	0.15	0	1
Worker	396	0.26	0.09	0	1
Htworker	396	0.002	0.007	0	0.078
Otworker	396	0.04	0.07	0	1
nonworker	396	0.73	0.23	0	0.8

Summary statistics Area C (death=244)

Variable	Obs	Mean	Std. Dev.	Min	Max
sucydeath	513	.48	1.62	0	21
b4	513	.48	.50	0	1
b5	513	.34	.47	0	1
b6	513	.16	.37	0	1
topodumy	513	.41	.49	0	1
dcypath	513	45.46	19.71	7.4	83
surge1	513	1.38	1.18	.6	4.7
dcoast	513	10.09	6.1	.3	30.67
mangrove	513	1.24	2.61	0	10
dmajriver	513	2.47	2.76	.05	26.48
dminriver	513	3.22	3.04	.08	19.1
droad	513	3.76	2.79	.06	18.17
roadumy	513	.62	.48	0	1
pop99	513	746.23	739.28	2	6098
literate	513	.56	.14	0	1.85
schedulecaste	513	.13	.19	0	1.08
worker	513	.26	.11	0	1.34
hhworker	513	.002	.007	0	.07
otworker	513	.04	.06	0	1.2
nonworker	513	.72	1.00	0	0.8

Summary Statistics – Area D (death=284)

variables	obs	mean	Std.dev	max	min
Sucydeath	897	0.315	1.26	0	21
B1	897	0.129	0.33	0	1
B2	897	0.132	0.34	0	1
B3	897	0.158	0.36	0	1
B4	897	0.279	0.45	0	1
B5	897	0.198	0.39	0	1
B6	897	0.106	0.308	0	1
Topodumy	897	0.237	0.426	0	1
Dcypath	897	43.67	16.6	7.4	83
Surge	897	1.26	0.928	0.6	4.7
Dcoast	897	15.1	8.8	0.3	38.74
Mangrove	897	1.29	2.36	0	10
Dmajriver	897	3.28	4.25	0.05	6.8
Dminriver	897	2.82	2.61	0.01	19.1
Droad	897	3.66	3.36	0.06	18.17
Roadumy	897	0.68	0.47	0	1
Pop99	897	851.3	789.98	2	6098
Literate	897	0.60	0.13	0	1
Schedulecaste	897	0.16	0.19	0	1
Worker	897	0.24	0.09	0	1
Htworker	897	0.003	0.007	0	0.078
Otworker	897	0.05	0.05	0	1
nonworker	897	0.72	0.72	0	0.8

Poisson Results- Area A: Dependant Variable = sucydeath, 428 villages

Inde. Variable	Equation 1	Equation 2	Equation 3	Equation 4
B4	-1.18*** (-3.06)	-----	-----	-1.16*** (-2.99)
B5	-----	-----	-----	-----
Topodumy	0.71*** (3.14)	0.97*** (4.61)	1.01*** (4.82)	0.77*** (3.43)
Dcypath	0.03** (2.15)	-0.003 (-0.33)	-0.3 (-0.31)	0.027** (2.15)
Surge	0.12* (1.81)	0.116* (1.76)	0.119** (1.86)	0.12* (1.83)
Dcoast	0.034 (1.5)	0.028 (1.23)	0.021 (0.92)	0.028 (1.24)
Mangrove	-0.81*** (-5.02)	-0.745*** (-5.0)	-0.79*** (-5.12)	-0.84*** (-5.12)
Dmajriver	0.007 (0.15)	-0.017 (-0.36)	-0.024 (-0.50)	0.0001 (0)
Dminriver	-0.18** (-2.03)	-0.111** (-2.1)	-0.13** (-2.48)	-0.122** (-2.32)
Droad	-0.008 (-0.26)	0.02 (0.66)	0.011 (0.37)	-0.016 (-0.52)
Roadumy	-0.194 (-1.22)	-0.144 (-0.92)	-0.117 (-0.76)	-0.159 (-1.01)
Pop99	0.0005*** (10.8)	0.0005*** (11.5)	0.0006*** (10.9)	0.0005*** (10.6)
Literate	-0.95 (-1.41)	-1.18* (-1.79)	-1.18* (-1.78)	-0.96 (-1.44)
Schedulecaste	-1.76*** (-2.98)	-1.84*** (-3.08)	-2.14*** (-3.37)	-2.00*** (-3.17)
Worker	-0.64 (-0.67)	-0.233 (-0.25)	-----	-----
Htworker	-----	-----	24.99*** (2.71)	26.99*** (2.82)
Otworker	-----	-----	-3.02* (-1.87)	-3.60** (-2.16)
Nonworker	-----	-----	-0.57** (-2.2)	-0.46** (-1.95)
constant	-1.08 (-1.46)	-0.68 (-0.95)	-0.22 (-0.31)	-0.84 (-1.15)

*** is significant at 1%, ** is significant at 5 % and * is significant at 10 %. Bracketed figures are the z values.

Poisson Results – Area B ; Dependant Variable = sucydeath, 396 villages

Inde.variable	Equation 1	Equation 2	Equation 3	Equation 4
B4	-1.14*** (-2.70)	-----	-----	-1.09*** (-2.58)
B5	-----	-----	-----	-----
Topodumy	0.96*** (3.89)	1.23*** (5.45)	1.26*** (5.56)	0.99*** (3.98)
Dcypath	0.018 (1.47)	-0.007 (-0.84)	-0.007 (-0.87)	0.018 (1.37)
Surge	0.098 (1.47)	0.104 (1.56)	0.111 (1.64)	0.106* (1.57)
Dcoast	0.023 (0.97)	0.23 (0.97)	0.015 (0.63)	0.016 (0.68)
Mangrove	-1.201*** (-5.55)	-1.07*** (-5.54)	-1.13*** (-5.69)	-1.24*** (-5.65)
dmajriver	0.33 (0.68)	0.007 (0.14)	-0.002 (-0.04)	0.024 (0.49)
Dminriver	-0.07 (-1.28)	-0.083 (-1.53)	-0.102** (-1.92)	-0.088* (-1.65)
Droad	-0.034 (-0.48)	0.005 (0.14)	-0.003 (-0.11)	-0.39 (1.10)
Roadumy	-0.287* (-1.77)	-0.25 (-1.58)	-0.235 (-1.48)	-0.25* (-1.6)
Pop99	0.0005*** (9.9)	0.0005*** (10.5)	0.0005*** (10.1)	0.0005*** (9.8)
Literate	-1.22* (-1.74)	-1.52** (-2.23)	-1.53** (-2.18)	-1.21* (-1.69)
Schedulecaste	-1.43** (-2.44)	-1.54*** (-2.62)	-1.83*** (-2.98)	-1.67*** (-2.7)
Worker	-1.29 (-1.6)	-0.63 (-0.56)	-----	-----
Htworker	-----	-----	23.54** (2.57)	25.01*** (2.65)
Otworker	-----	-----	-2.79* (-1.76)	-3.43** (-2.07)
Nonworker	-----	-----	-0.57** (-2.23)	-0.48** (-2.04)
constant	-0.37 (-0.47)	-0.21 (-0.27)	0.19 (0.27)	-0.24 (-0.33)

*** is significant at 1 %, ** is significant at 5 % and * is significant at 10 %. Bracketed values are the z values.

Poisson Results –Area C; Dependant variable = sucydeath, 513 villages.

Depe.variable	Equation 1	Equation 2	Equation 3	Equation4
B4	0.21 (0.44)	-----	-----	0.08 (0.18)
B5	1.30* (1.85)	-----	-----	1.14 (1.58)
B5	-----	-----	-----	-----
Topodummy	0.74*** (3.31)	0.97*** (4.73)	0.99*** (4.82)	0.78*** (3.49)
Dcoypath	0.024** (1.99)	-0.0002 (-0.03)	0.0005 (0.08)	0.23* (1.88)
Surge	0.129** (2.01)	0.132** (2.05)	0.138** (2.13)	0.132** (2.03)
Dcoast	0.034 (1.6)	0.035* (1.83)	0.033* (1.68)	0.03 (1.44)
Mangrove	-0.645*** (-4.68)	-0.619*** (-4.85)	-0.639*** (-4.4)	-0.66*** (-4.67)
Dmajriver	0.033 (0.99)	0.027 (0.86)	0.027 (0.85)	0.028 (0.85)
Dminriver	-0.102** (-2.41)	-0.096** (-2.24)	-0.107** (-2.50)	-0.111*** (-2.65)
Droad	-0.01 (-0.30)	0.015 (0.52)	0.007 (0.26)	-0.02 (-0.56)
Roadummy	-0.176 (-1.15)	-0.123 (-0.82)	-0.103 (-0.68)	-0.15 (-0.99)
Pop99	0.0005*** (10.9)	0.0005*** (11.8)	0.0005*** (10.9)	0.0005*** (10.3)
Literate	-1.08* (-1.72)	-1.31** (-2.12)	-1.34** (-2.11)	-1.15* (-1.82)
Sche.caste	-1.41** (2.67)	-1.46** (-2.78)	-1.71*** (-3.08)	-1.67*** (-2.99)
Worker	-0.56 (-0.59)	-0.103 (-0.12)	-----	-----
Htworker	-----	-----	21.35** (2.38)	24.36*** (2.62)
Otworker	-----	-----	-1.72 (-1.19)	-2.07 (-1.24)
Nonworker	-----	-----	-0.55** (2.16)	-0.47** (-2.01)
constant	-2.45* (-2.07)	-0.99 (-1.56)	-0.59 (-0.97)	-1.98* (-1.68)

Poisson Result – Area D; Dependant variable = sucydeath, 897 villages

Inde.variable	Equation 1	Equation 2	Equation 3	Equation 4
B1	-0.84 (-1.59)	-----	-----	-0.83 (-1.56)
B2	-0.05 (-0.09)	-----	-----	-0.06 (-0.12)
B3	-15.9 (-0.01)	-----	-----	-15.38 (-0.02)
B4	0.18 (0.41)	-----	-----	0.09 (0.2)
B5	1.27* (1.88)	-----	-----	1.13* (1.69)
B6	-----	-----	-----	-----
Topodummy	0.70*** (3.42)	1.03*** (5.41)	1.09*** (5.72)	0.75*** (3.6)
Dcoypath	0.019* (1.68)	-0.006 (-1.07)	-0.005 (-0.94)	0.019 (1.59)
Surge	0.13** (2.07)	0.222*** (3.68)	0.22*** (3.63)	0.133*** (2.08)
Dcoast	0.014 (0.91)	-0.013 (-1.04)	-0.014 (-1.11)	0.013 (0.86)
Mangrove	-0.626*** (-4.57)	-0.684*** (-5.5)	-0.723*** (-5.69)	-0.639*** (4.62)
Dmajriver	0.036 (1.53)	0.03** (1.92)	0.034** (1.97)	0.034 (1.44)
Dminriver	-0.089** (-2.29)	-0.064* (-1.65)	-0.077** (-1.97)	-0.098*** (-2.53)
Droad	-0.03 (-1.18)	-0.017 (-0.76)	-0.02 (-0.98)	-0.034 (-1.33)
Roadummy	-0.18 (-1.29)	-0.16 (-1.13)	-0.153 (-1.09)	-0.166 (-1.17)
Pop99	0.0005*** (11.4)	0.0005*** (12.15)	0.0005*** (11.4)	0.0005*** (11.0)
Literate	-0.91 (-1.5)	-1.91*** (-3.3)	-1.80*** (-3.05)	-0.98* (-1.61)
Sche.caste	-1.03** (2.24)	-1.3*** (-2.83)	-1.42*** (-2.95)	-1.22*** (-2.56)
Worker	-0.47 (-0.54)	0.48 (0.64)	-----	-----
Htworker	-----	-----	18.87** (2.15)	20.46** (2.26)
Otworker	-----	-----	-2.54* (-1.75)	-1.81 (-1.25)
Nonworker	-----	-----	-0.62** (-2.3)	-0.45** (-1.94)
constant	-2.12** (-1.99)	-0.34 (-0.61)	0.19 (0.36)	-1.72 (-1.54)

Prediction based on Equation 3 of Area D results.

Predicted human death without and with the mangrove forest = 387-283 = 104

Combined marginal effect of topography dummy and mangrove vegetation = 0.1154.

Conclusion: -

1. Mangrove forest seems to have played a strong protective role in averting human death during the super cyclone of Oct. 1999.
2. The result is robust and independent of the sample size.
3. Without the forest, it seems, another 104 persons would have died in area D or in those 897 villages.
4. The combined effect of topography dummy and mangrove vegetation being positive, it seems, even if we grow mangrove in all low lying vulnerable areas where mangrove existed historically, human casualties can't be averted 100 %. Few casualties will still occur. But there could be substantial reduction in death.

GRAM PANCHYATS- PURI (Casuarinas areas)



Summary Statistics- Casuarinas areas (Death=188, only wind)

variables	obs	mean	Std.dev	min	max
sucydeath	391	0.4808	1.1849	0	10
Dcoast	391	8.7009	4.3524	0.37	18
Dcypath	391	33.8929	4.1084	25	45
Casuarinas	391	0.9904	0.9539	0	2.8
Native forest	391	0.1339	0.4529	0	2.2
Droad	391	2.4634	2.0935	0.06	10.65
Pop-1999	391	820.4629	860.3337	11	7270
Literate	391	0.6687	0.2963	0	0.83
Sche.caste	391	0.2189	0.2332	0	1
worker	391	0.3159	0.1355	0.1739	0.5469

Poisson Result (casuarinas areas), Dept.var = sucydeath

Inde.var	Coef	z	P> z
rddmy	-.4774582	-2.49	0.013
Dcoast	-.1489863	-5.44	0.000
Dcypath	-.2214735	-6.92	0.000
Casuarinas	-.1773471	-1.67	0.095
Native forest	-.3028221	-1.37	0.171
Droad	.0426315	0.84	0.400
Driver	.0054494	0.09	0.932
pop_1999	.0003825	7.79	0.000
Literate	2.972111	2.29	0.022
Sche.caste	.3295678	0.87	0.384
Worker	.4702554	0.27	0.788
Nonworker	.0646499	0.74	0.458
marworker	-.2593642	-0.18	0.857
_cons	5.62582	3.84	0.000

Comparison of Marginal effect

Forest type	Obs	Mean	Std. Dev.	Min	Max
Casuarinas	391	-.085	.142	-1.687	-.0061
Native forest	391	-.146	.243	-2.881	-.0105
Mangroves	427	-.615	1.208	-11.414	-1.26e-0

Conclusion

- Casuarinas forest, the shelterbelt plantation of government, have low protective capacity for human life compared to other forests.
- Mixed indigenous forests seems to be having better protective capacity than casuarinas.

Poisson Result – Area D; Dependant variable = sucydeath, 897 villages

Inde. variable	Equation 1	Equation 2	Equation 3	Equation 4
B1	-0.84 (-1.59)	-----	-----	-0.83 (-1.56)
B2	-0.05 (-0.09)	-----	-----	-0.06 (-0.12)
B3	-15.9 (-0.01)	-----	-----	-15.38 (-0.02)
B4	0.18 (0.41)	-----	-----	0.09 (0.2)
B5	1.27* (1.88)	-----	-----	1.13* (1.69)
B6	-----	-----	-----	-----
Topodumy	0.70*** (3.42)	1.03*** (5.41)	1.09*** (5.72)	0.75*** (3.6)
Dcypath	0.019* (1.68)	-0.006 (-1.07)	-0.005 (-0.94)	0.019 (1.59)
Surge	0.13** (2.07)	0.222*** (3.68)	0.22*** (3.63)	0.133*** (2.08)
Dcoast	0.014 (0.91)	-0.013 (-1.04)	-0.014 (-1.11)	0.013 (0.86)
Mangrove	-0.626*** (-4.57)	-0.684*** (-5.5)	-0.723*** (-5.69)	-0.639*** (4.62)
Dmajriver	0.036 (1.53)	0.03** (1.92)	0.034** (1.97)	0.034 (1.44)
Dminorriver	-0.089** (-2.29)	-0.064* (-1.65)	-0.077** (-1.97)	-0.098** (-2.53)
Droad	-0.03 (-1.18)	-0.017 (-0.76)	-0.02 (-0.98)	-0.034 (-1.33)
Roadumy	-0.18 (-1.29)	-0.16 (-1.13)	-0.153 (-1.09)	-0.166 (-1.17)
Pop99	0.0005*** (11.4)	0.0005*** (12.15)	0.0005*** (11.4)	0.0005*** (11.0)
Literare	-0.91 (-1.5)	-1.91*** (-3.3)	-1.80*** (-3.05)	-0.98* (-1.61)
Sche.caste	-1.03** (2.24)	-1.3*** (-2.83)	-1.42*** (-2.95)	-1.22** (-2.56)
Worker	-0.47 (-0.54)	0.48 (0.64)	-----	-----
Hwworker	-----	-----	18.87** (2.15)	20.46** (2.26)
Owworker	-----	-----	-2.54* (-1.75)	-1.81 (-1.25)
Nonworker	-----	-----	-0.62** (-2.3)	-0.45** (-1.94)
constant	-2.12** (-1.99)	-0.34 (-0.61)	0.19 (0.36)	-1.72 (-1.54)

Poisson Result – Area D; mi ≤ 1.5 km; No of villages = 626.

Inde. variable	Equation 1	Equation 2	Equation 3	Equation 4
B1	-0.42 (-0.74)	-----	-----	-0.47 (-0.85)
B2	0.29 (0.52)	-----	-----	0.23 (0.40)
B3	-11.26 (-0.02)	-----	-----	-10.91 (-0.02)
B4	0.325 (0.64)	-----	-----	0.19 (0.41)
B5	1.97*** (2.72)	-----	-----	1.68** (2.30)
B6	-----	-----	-----	-----
Topodumy	0.56*** (2.66)	0.99*** (5.21)	1.03*** (5.35)	0.60*** (2.80)
Dcypath	0.02** (1.95)	-0.01 (-1.56)	0.0009 (-1.5)	0.02* (1.71)
Surge	0.081 (1.25)	0.20*** (3.28)	0.197*** (3.21)	0.08 (1.31)
Dcoast	-0.007 (-0.46)	-0.03** (-1.97)	-0.025(-1.87)	-0.004 (-0.29)
mi	-1.31*** (-5.49)	-0.96*** (-4.36)	-1.02*** (-4.57)	-1.28*** (-5.40)
Dmajriver	0.069*** (2.82)	0.051** (2.43)	0.051** (2.49)	0.06** (2.53)
Dminorriver	-0.102** (2.57)	-0.08** (-2.09)	-0.09** (-2.37)	-0.11*** (-2.77)
Droad	-0.06** (-2.28)	-0.02 (-1.02)	-0.031 (-1.30)	-0.06** (-2.33)
Roadumy	-0.21 (-1.45)	-0.15 (-1.03)	-0.129 (-0.91)	-0.16 (-1.14)
Pop99	0.0004*** (10.75)	0.0004*** (11.2)	0.0004*** (10.36)	0.0004*** (9.9)
Literare	-0.86 (-1.35)	-2.06*** (-3.48)	-2.06*** (-3.39)	-1.08** (-1.74)
Sche.caste	-0.36 (-0.83)	-0.75* (-1.72)	-0.90** (-1.97)	-0.61 (-1.34)
Worker	-1.57 (-1.47)	-0.01 (-0.01)	-----	-----
Hwworker	-----	-----	17.6** (1.98)	18.88** (2.04)
Owworker	-----	-----	-1.52 (-1.13)	-1.18 (-0.85)
Nonworker	-----	-----	-0.66** (-2.45)	-0.46** (-2.07)
constant	-1.93* (-1.70)	0.25 (0.43)	0.72 (1.29)	-1.62 (-1.39)

Poisson Result – Area D; Mi ≤ 0.8 (0 to 0.76); 567 villages

Inde. variable	Equation 1	Equation 2	Equation 3	Equation 4
B1	-0.71 (-1.32)	-----	-----	-0.69 (-1.25)
B2	-0.07 (-0.14)	-----	-----	-0.05 (-0.09)
B3	-----	-----	-----	-----
B4	0.09 (0.16)	-----	-----	0.03 (0.07)
B5	1.78** (2.41)	-----	-----	1.55** (2.08)
B6	-----	-----	-----	-----
Topodumy	0.54** (2.47)	0.93** (4.62)	0.86*** (4.26)	0.56** (2.54)
Dcypath	0.02 (1.50)	-0.01* (-1.74)	-0.01* (-1.84)	0.017 (1.43)
Surge	0.03 (40)	0.18*** (2.87)	0.20*** (3.22)	0.04 (0.65)
Dcoast	-0.01 (-0.68)	-0.03** (-2.39)	-0.03** (-2.56)	-0.008 (-0.43)
mi	-0.72** (-1.96)	-0.65** (-1.76)	-0.83** (-2.23)	-0.68* (-1.83)
Dmajriver	0.05** (2.03)	0.04* (1.61)	0.04* (1.83)	0.05* (1.79)
Dminorriver	-0.09** (-2.20)	-0.07** (-1.79)	-0.09** (-2.12)	-0.09** (-2.29)
Droad	-0.07** (-2.24)	-0.02 (-0.72)	-0.02 (-0.85)	-0.06** (-2.13)
Roadumy	-0.22 (-1.44)	-0.17 (-1.15)	-0.12 (-0.79)	-0.17 (-1.1)
Pop99	0.0005*** (10.7)	0.0005*** (10.9)	0.0005*** (10.4)	0.0005*** (10.2)
Literare	-0.38 (-0.55)	-1.8*** (-2.83)	-1.48** (-2.27)	-0.57 (-0.87)
Sche.caste	-0.19 (-0.42)	-0.60 (-1.27)	-0.59 (-1.20)	-0.40 (-0.86)
Worker	-2.02** (-1.89)	-0.31 (-0.37)	-----	-----
Hwworker	-----	-----	16.37* (1.87)	17.5** (2.0)
Owworker	-----	-----	-1.96 (-1.37)	-1.01 (-0.75)
Nonworker	-----	-----	-0.29 (-0.86)	-0.19 (-0.67)
constant	-1.58 (-1.33)	0.32 (0.49)	0.12 (0.20)	-1.83 (-1.59)