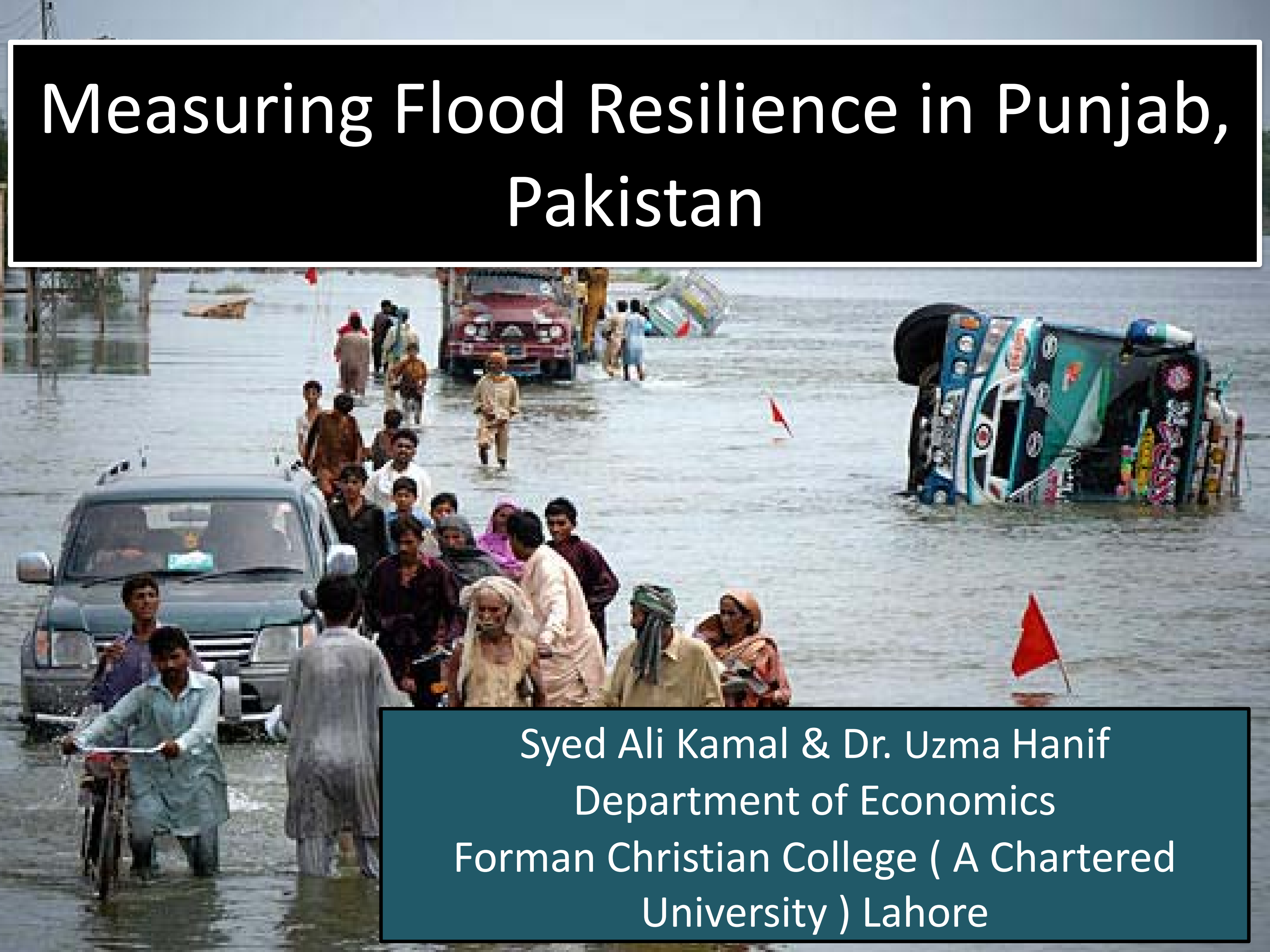

Measuring Flood Resilience in Punjab, Pakistan

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Outline

- Introduction
- Review of literature
- Theoretical Framework
- Methodology
- Results
- Policy Recommendations

Introduction

- Pakistan is naturally vulnerable to flood hazard.
- The combined financial loss incurred by the floods from 1950 to 2009 amounts to **$20 billion,** 8,887 people died.
- The 2010 floods alone resulted in a combined financial loss of **$10 billion** along with 2,000 causalities.
- Major flood events in the history of Pakistan are: 1950, 1956, 1957, 1973, 1976, 1978, 1988, 1992, 2010, 2011, 2012, 2013, 2014, and 2015.
- After viewing the damages the question of Resilience arises

Objectives of the Research

- To identify the flood resilience determinants in Punjab by taking the data of 13 districts
  - Application of a flood damages approaches for valuing the resilience in Punjab
  - Panel data collection, compilation, and analysis
  - Conduct economic analysis

Review of Literature

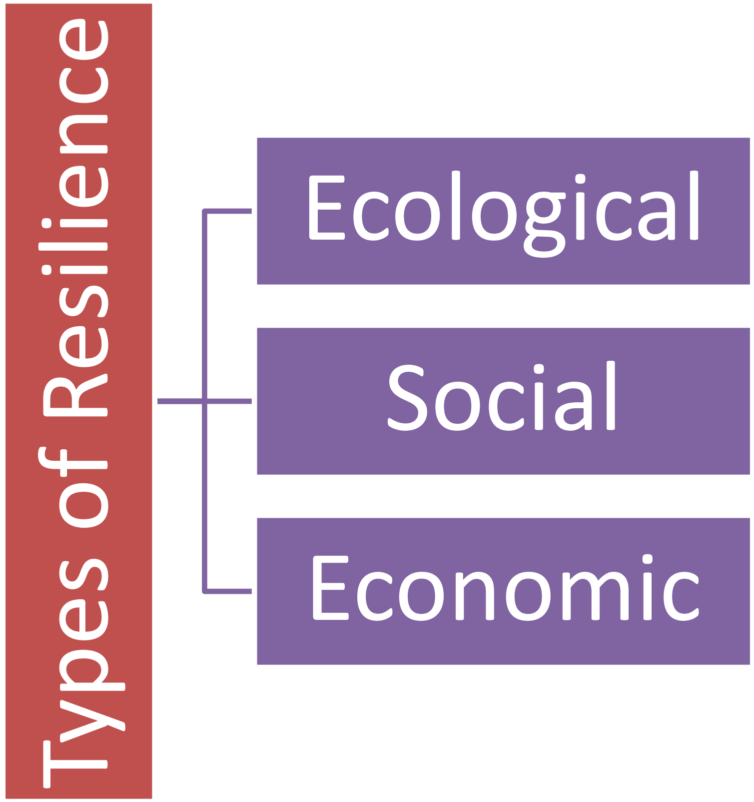
Climate Change and floods in Pakistan

- Climate change has triggered the frequency and intensity of natural disasters (Pachauri and Reisinger, 2007).
- For the past seven years, Pakistan has been among the top ten countries worst affected due to extreme weather events, (Global Climate Risk Index by Germanwatch) securing first place in 2010.
- Within the Indus basin system flash floods are expected to increase in the uplands (300-3000m) whereas riverine and coastal floods are expected to increase in the lowlands (<300m) (Xu et al, 2009).

Impact of Natural Disasters on Economic Growth (Short Run)				
Studies	Approach	Time periods	Sample	Results
Raddatz (2007)	Panel- VAR framework	1965-1997	40 countries	Negative Relationship
Raddatz (2009)	Panel study	1975-2006	112 countries	Negative relationship
Noy (2009)	Panel study	1970-2003	109 countries	Negative relationship
Cavallo et al. (2009)	Comparative study	1968-2002	202 countries	Negative relationship
Impact of Natural Disasters on Economic Growth (Long run)				
Skidmore and Toya (2002)	Cross-sectional	1960-1990	89 countries	Expansionary effect
Noy and Nualsri (2008)	Panel- VAR framework	1990-2005	44 countries	Negative effect
Raddatz (2009)	Panel study	1975-2006	112 countries	Negative effect
Leiter et al (2009)	Difference in difference approach (DID)	1980 -2008	Firm level	Positive effect

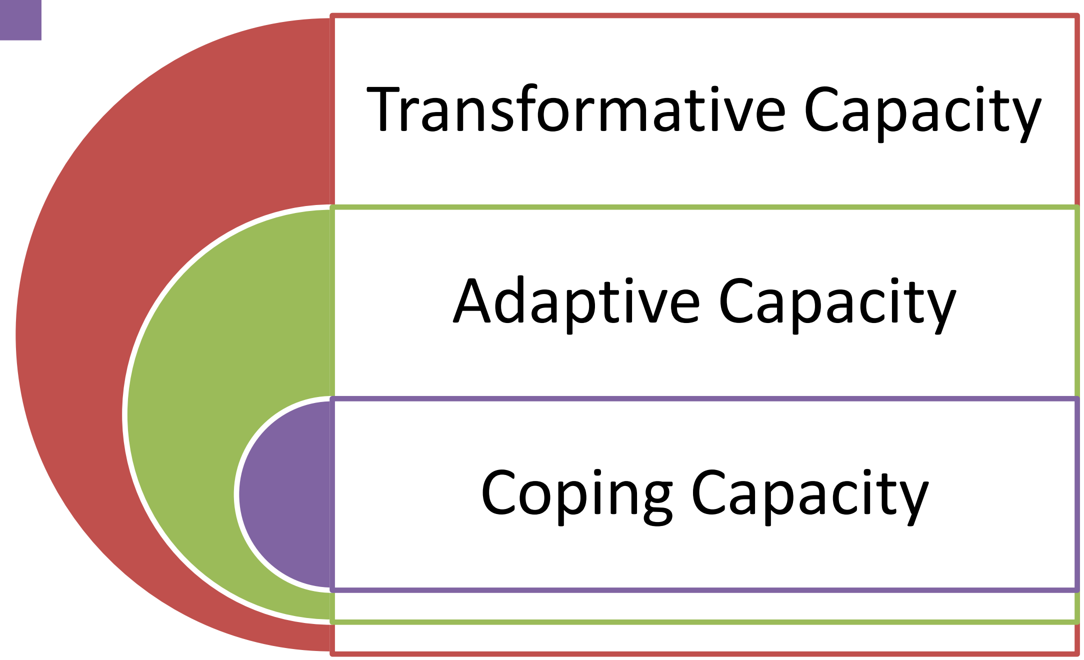
Resilience

- Resilience can be defined as the capacity of a system to **absorb** a **disturbance** or shock, and then re-organize or **restore** into a fully functional system.
- It includes not only a system's capacity to return to the same state that existed before the disturbance but also to improve that state through learning and adaptation (Adger et al., 2005; Folke, 2006).



Batica and Gourbesville, 2012

Resilience is composed of



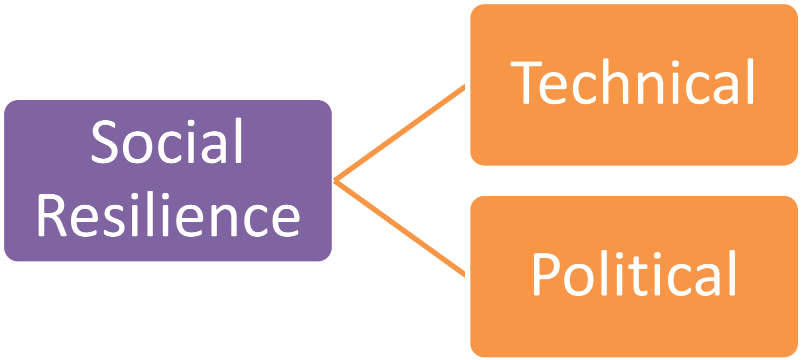
Keck and Sakdapolrak, 2013

Godschalk, 2003

A Socially Resilient System can endure stress on

- Health
- Education
- Social Welfare
- Employment

Adger, 2000



Keck and Sakdapolrak, 2013

Causes of Deficient Flood Resilience in Pakistan

- Land use Changes
- Environmental Degradation
- Construction of built environment

Oxley, 2011

- Poor water use practices
- Hydrological priorities of policy makers

Mustafa and Wrathal, 2011

Resilience can be improved by

- Learning about the past mistakes
- Developing Flood management options
- Creating effective linkages
- Mutual trust, integrity, and confidence
- Flood adaptation

Marrero and Tshakert, 2011

- Institutional interplay
- Communication of risk

Schelfaut et al., 2011

Measurement of Resilience

- The measurement of resilience is an emerging development concept.
- The identification of the measurement standards of resilience is still a big challenge.
- There is currently no agreement on any one particular way to measure resilience (Mitchell, A., 2013; Winderl, T., 2014).
- Indices have been made to capture resilience at global, national, sub national level and even the household level.

Authors	Scale of the study	Study Area	Estimation technique
Chang and Shinozuka (2004)	Earthquake resilience at city level	Memphis, Tennessee USA	earthquake loss estimation model
Rose, A. (2004)	Earthquake Resilience	USA	Computable General Equilibrium (CGE)
Cutter et al. (2008)	resilience assessment at local and community level	USA	Disaster Resilience of Place (DROP)
Cimellaro et al (2010)	Earthquake resilience framework for hospital building	California State of USA	Recovery Model
Renschler et al, (2010)	Disaster Resilience at Community level		PEOPLES Resilience Framework
Cutter et al (2010)	Urban vs Rural Resilience	Florida, USA	Baseline Characteristics Approach
Frazier et al. (2013)	Flood and disaster Resilience	Sarasota county Florida	Place specific, diff. weighting , spatio - temporal approach
Nguyen and James (2013)	Flood Resilience	Mekong River Delta , China	Subjective well-being approach

Resilience Measurement	Developing Organization	Focus	Components	Unit of Analysis	Methodology
Hyogo Framework for Action	UNISDR	progress towards HFA using 31 indicators on three levels (outcomes, goals, priorities)	outcome indicators, priority areas and strategic goals	local government level	self-assessment by governments on scale from 1 to 5; mostly input-related
Global Focus Model	Maplecroft and UN OCHA	hazards, vulnerabilities and response capacity at country-level	vulnerability, hazard, humanitarian need	country level	quantitative; weighted composite index
World Risk Index	UNU-EHS	disaster risk value for 173 countries	susceptibility, exposure, coping capacities, adaptation	country level	Composite weighted index with 28 indicators
Socio Economic Resilience Index	Maplecroft	socio-economic resilience	Unknown	country level	Unknown
ResilUS	Western Washington University	prototype simulation model of community resilience in U.S.	loss estimation module and recovery module	community level (USA)	not known

Flood Profile of Punjab

Years	2010	2011	2012	2013	2014	2015	Total Damages
Month of Flooding	July	September	September	August	September	July	
Causes of Flood	Riverine flood in Indus Chenab and Jhelum	Riverine flood in Sutlej and Hill torrents	Riverine flooding, Hill torrents and heavy rainfall	Riverine flooding in Chenab and Sutlej Nullahs	Riverine flooding in Jhelum/Chenab Nullahs	Riverine flood in Indus and Torrential rains	
Affected Districts	11	12	3	9	16	8	**59**
Affected Villages	1810	335	110	1628	3484	558	**7925**
Affected Population	6.2 million	.026 Million	.389 million	.120 million	2.47 million	o.445 million	**9.884 million**
Deaths	262	4	60	109	286	35	**756**
House Damages	353,141	1,284	25,556	3,378	83,593	16,374	**483,326**
Affected Area (acre)	5.23 million	.270 million	1.96 million	.195 million	2.41 million	0.34 million	**10.405 million**
Livestock Loss	3572	59	898	81	737	0	**5347**

Conceptual Framework

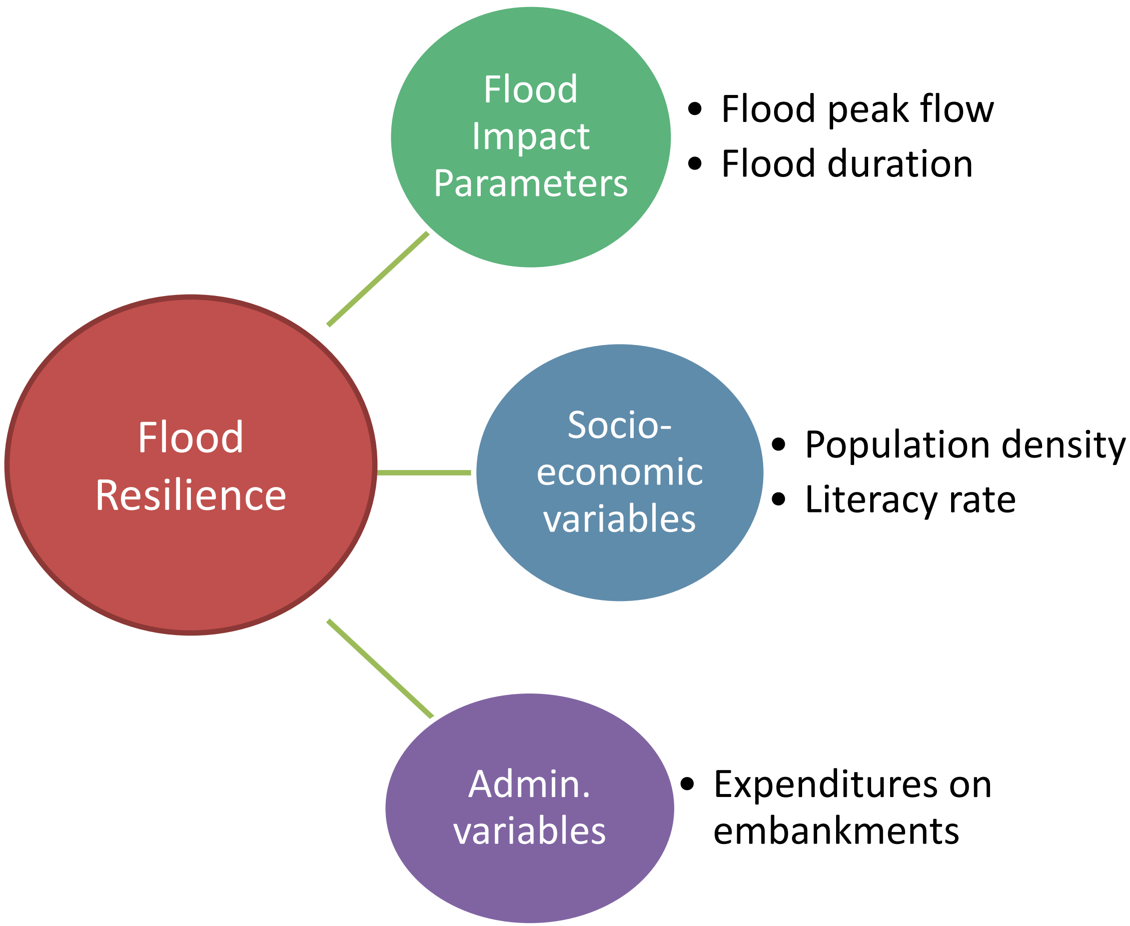
Resilience Approach

- Resilience quantification is in its early stages of development and presently there exists no agreement on the most proficient method to measure resilience. (Béné, 2013; Mitchell, 2013)
- Quantification of resilience to natural disasters can be conducted in a number of ways using different methods and various approaches.
  - Well being Approach
  - Vulnerability Approach
  - Capacity to cope, adapt and transform approach
  - Recovery Approach
  - Damages Approach

Damages Approach

- Based on evaluating and measuring the effect of calamities.
- The shocks, losses, or damages in themselves are considered to be a set of measures of resilience (Winderl, 2014).
- *EM-DAT*, *DesInventar*, *The PREVIEW Global Risk data Platform*, are all examples of initiatives that measure the shocks, losses, or stress of the natural disasters.
- In this study we use the damages caused by floods to measure the resilience.
- We developed a damage function where dependent variable is the damages and independent variables are the various damage influencing variables.

Conceptual Framework of Model



- Flooding for a longer duration is likely to cause more damages than a short lived flood (Jonkman et al., 2008; Merz et al., 2004; Merz et al, 2013).
- Flood peak flow has been chosen as a relevant flood impact parameter in accordance with the practices of FFD.
- Greater population density means greater house damage and a greater loss of life.
- Adult literacy rate as a proxy for knowledge of flood hazard or awareness (Messner and Meyer, 2006; Merz, et al., 2013)
- Expenditure on embankments is used as a proxy variable representing precautionary measures (Thieken et al., 2005)

The Damage Function

- D_{it}= d (F_{it}, S_{it}, A_{it})

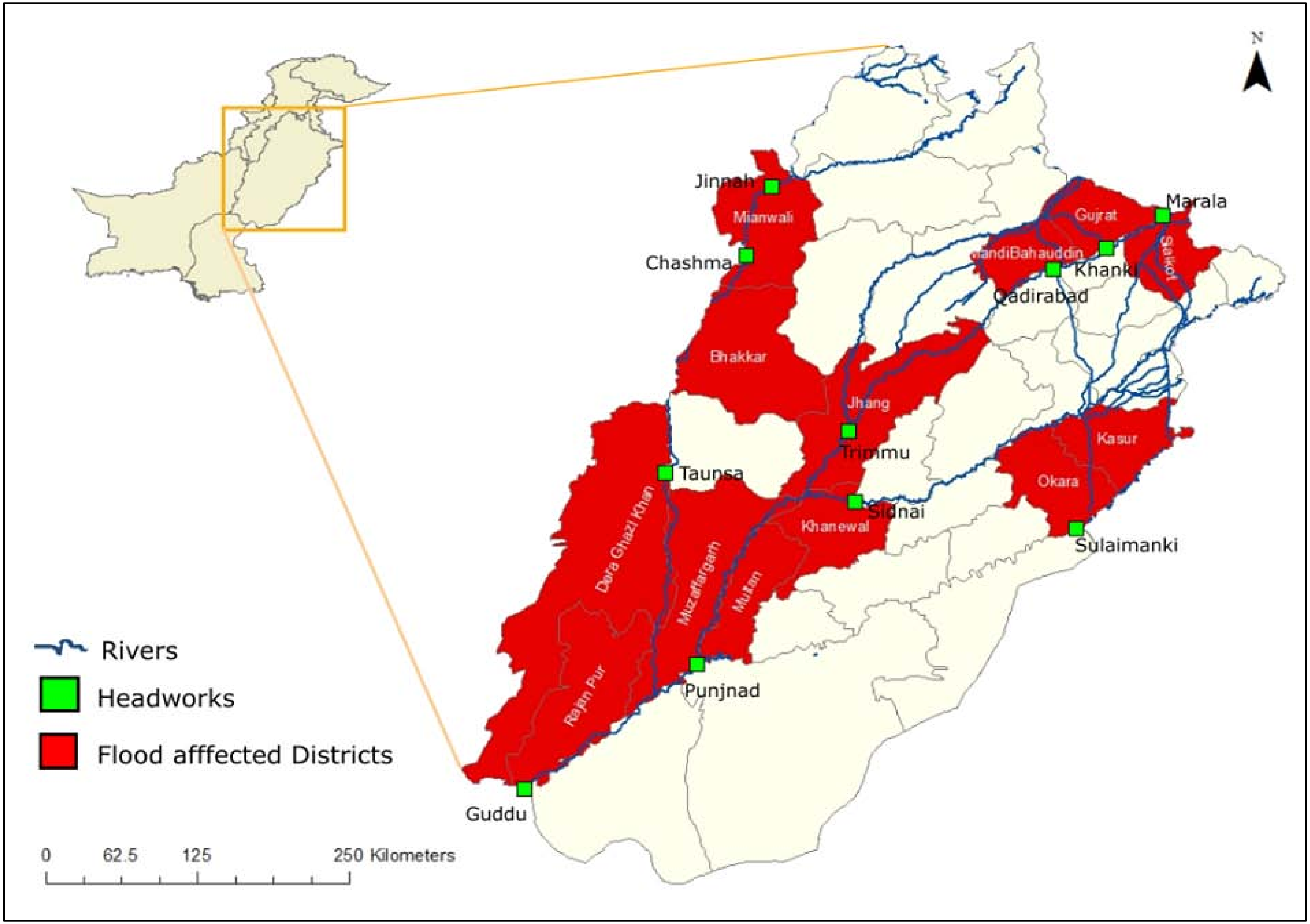
- In the above equation “i” represents the location and “t” represents the time period.
- D = Damages suffered where D incorporates affected crop area, house damage, livestock damage, and human casualties at cross-section i and time period t.
- F = flood variables at cross-section i and time period t.
- S= Socioeconomic variables at cross section i and time period t.
- A= Administrative variables at cross-section i and time period t.
- The above mentioned damage function has been estimated using multivariate regression.

Methodology

Study Area

- In this study data from 13 districts across the Punjab were used. These districts include:
  - Mianwali and Bhakkar in the north western region,
  - Districts Sialkot, Gujrat and Mandi Bahaudin in the north eastern region.
  - Districts Jhang and Khanewal in the central region,
  - Districts Kasur and Okara in the eastern region and
  - Districts D.G. Khan, Rajanpur, Muzaffargarh and Multan in the southern region.

Study Area


N
Jinnah
Mianwali
Chashma
Bhakkar
Marala
Gujrat
MandiBahauddin
Sialkot
Khanki
Qadirabad
Jhang
Trimmu
Taunsa
Sidnai
Khanewal
Kasur
Okara
Sulaimanki
Dera Ghazi Khan
Muzaffargarh
Multan
Rajan Pur
Punjnad
Guddu
Rivers
Headworks
Flood afffected Districts
0
62.5
125
250 Kilometers

Definition of Variables

Dependent Variables

Variables	Title	Definition	Source of Data
Affected Crop Area	ACA	Crop Area affected by floods measured in Acres	PDMA Punjab (2010-2015)
House Damage	HD	Number of houses damaged due to floods.	PDMA Punjab (2010-2015)
Number of Persons dead	NPD	Number of dead persons due to flood	PDMA Punjab (2010-2015)
Livestock Damage	LD	Number of animals dead or lost during the floods	PDMA Punjab (2010-2015)

Independent variables

Variables	Title	Definition	Source of Data
Flood peak flow	FF	Flood flow at its peak for a duration of six hours. (cusecs/6hrs)	Pakistan Meteorology Department
Flood duration	FD	Duration of flood flow above the flood limit (days)	Pakistan Meteorology Department
Literacy Rate	LR	Adult literacy rate at the district level (percent)	Punjab Development statistics
Population Density	PD	Number of persons per square kilometer	Punjab Development statistics
Average Elevation	AE	Height above the sea level (feet)	Pakistan Meteorology Department
Expenditure on Embankments	EE	Amount of money spent on construction of embankments (Rupees in millions)	Irrigation Department, Punjab

The Panel Approach

- Characteristics of Panel data
- Traditional approaches for panel data
- Failure of Classical Linear Regression Model due to cross sectional dependence across cross sections
- Use of Feasible Generalized Least Square Approach
- FGLS estimator is **unbiased**, **efficient** and **consistent**.

Standard Model

- $\boldsymbol{D_{it} = \alpha + \beta_1 FF_{it} + B_2 FD_{it} + \beta_3 AE_{it} + \beta_4 PD_{it} + \beta_5 LR_{it} + \beta_6 EE_{it} + \varepsilon_{it}}$ ----- **(1)**
- Where i represent the cross section and t represents the time period
- D_{it}= damages in district i at time period t
- FF_{it}= Flood peak flow at the nearest barrage at district i and time period t
- FD_{it}= Flood Duration is the amount of time taken by the flood to pass through the nearest barrage at district i and time period t.
- AE_{it}= Average elevation of the district i and time period t
- LR_{it}= Literacy rate in the flood affected districts used as a proxy for Information at district i and time period t
- PD_{it}= Population Density of district i and time period t.
- EE_{it}= Expenditure on Embankments by the irrigation department in district i and time period t.

***Model 1*- Affected Crop Area Model**

$$ACA_{it} = \alpha_{1i} + \beta_{11}FF_{it} + \beta_{12}FD_{it} + \beta_{13}LR_{it} + \beta_{14}EE_{it} + \beta_{15}PD_{it} + \varepsilon_t \; .... (2)$$

ACA_{it}= Affected crop area at district i and time period t.

***Model 2* - House Damage Model**

$$HD_{it} = \alpha_{2i} + \beta_{21}FF_{it} + \beta_{22}FD_{it} + \beta_{23}LR_{it} + \beta_{24}EE_{it} + \beta_{25}PD_{it} + \mu_t \; .... (3)$$

HD_{it} = House Damage at cross section i and time period t

***Model 3* - Loss of Life Model**

$$NPD_{it} = \alpha_{3i} + \beta_{31}FF_{it} + \beta_{32}FD_{it} + \beta_{33}LR_{it} + \beta_{34}EE_{it} + \beta_{35}PD_{it} + \gamma_t \; .... (4)$$

NPD_{it}= Number of persons that died due to floods at district i and time period t

***Model 4* - Livestock Damage Model**

$$LD_{it} = \alpha_{4i} + \beta_{41}FF_{it} + \beta_{42}FD_{it} + \beta_{43}LR_{it} + \beta_{44}EE_{it} + \beta_{45}AE_{it} + \omega_t \; .... (5)$$

LD_{it}= Livestock Damage at district i and time period t

Results

VIF test Results

	EE	FD	FF	LR	PD
EE	1				
FD	1.00595	1			
FF	1.04173	2.34181	1		
LR	1.02398	1.14978	1.01014	1	
PD	1.01189	1.08616	1.08945	1.61981	1

- The results reveal that there is no problem of multicollinearity in the data.
- The problem exists if the value of VIF exceeds 10 as described by Gujrati et al (2009).

Model 1- Affected Crop Area Model

$$ACA_{it} = a_{1i} + \beta_{11}FF_{it} + \beta_{12}FD_{it} + \beta_{13}LR_{it} + \beta_{14}EE_{it} + \beta_{15}PD_{it} + \varepsilon_t$$

Variables	Coefficients	t- statistics	Prob.
C	66156.40	3.524433	0.0007
FF	0.120279	5.789266	0.0000
FD	6527.814	3.677928	0.0005
EE	$-6.28\text{x}10^{-5}$	-0.798972	0.4269
LR	-1421.348	-3.772440	0.0003
PD	10.86852	1.058941	0.2932
Weighted Statistics			
R-squared	0.630535	**Mean dependent var**	76659.03
Adjusted R-squared	0.604878	**S.D. dependent var**	147934.5
S.E. of regression	92553.76	**Sum squared resid**	6.17E+11
F-statistic	24.57529	**Durbin-Watson stat**	2.023787
Prob(F-statistic)	0.000000		

Model 2- House Damage Model

- $HD_{it} = \alpha_{2i} + \beta_{21}FF_{it} + \beta_{22}FD_{it} + \beta_{23}LR_{it} + \beta_{24}EE_{it} + \beta_{25}PD_{it} + \mu_t$

Variables	Coefficients	t- statistics	Prob.
C	12850.52	4.911987	0.0000
FF	0.007828	2.205193	0.0306
FD	523.9571	2.761605	0.0073
LR	-263.7707	-4.622445	0.0000
EE	2.56E-05	2.681068	0.0091
PD	2.349458	1.855652	0.0676
	Weighted Statistics		
R-squared	0.449526	**Mean dependent var**	0.471579
Adjusted R-squared	0.411298	**S.D. dependent var**	1.043982
S.E. of regression	0.797979	**Sum squared resid**	45.84746
F-statistic	11.75925	**Durbin-Watson stat**	1.788296
Prob(F-statistic)	0.000000		

Model 3- Loss of Life Model

- $NPD_{it} = \alpha_{3i} + \beta_{31}FF_{it} + \beta_{32}FD_{it} + \beta_{33}LR_{it} + \beta_{34}EE_{it} + \beta_{35}PD_{it} + \gamma_t$

Variables	Coefficients	t- statistics	Prob.
C	2.071576	2.215799	0.0299
FF	7.12E-06	3.616360	0.0006
FD	0.322774	3.752472	0.0004
LR	-0.074822	-3.504796	0.0008
EE	2.79E-09	0.716240	0.4762
PD	0.002952	3.843602	0.0003
Weighted Statistics			
R-squared	0.500372	**Mean dependent var**	0.613178
Adjusted R-squared	0.465675	**S.D. dependent var**	1.281860
S.E. of regression	0.999216	**Sum squared resid**	71.88709
F-statistic	14.42142	**Durbin-Watson stat**	2.041034
Prob (F-statistic)	0.000000		

Model 4- Livestock Damage Model

- $LD_{it} = \alpha_{4i} + \beta_{41}FF_{it} + \beta_{42}FD_{it} + \beta_{43}LR_{it} + \beta_{44}EE_{it} + \beta_{45}AE_{it} + \omega_t$

Variables	Coefficients	t- statistics	Prob.
C	26.18265	1.218879	0.2269
FF	0.000142	3.148093	0.0024
FD	-2.990709	-2.219329	0.0296
LR	-0.471030	-0.687076	0.4942
EE	2.89E-07	4.719586	0.0000
AE	-0.082828	-0.542110	0.5894
Weighted Statistics			
R-squared	0.247383	**Mean dependent var.**	0.308997
Adjusted R-squared	0.195118	**S.D. dependent var.**	0.924311
S.E. of regression	0.874341	**Sum squared resid**	55.04197
F-statistic	4.733242	**Durbin-Watson stat**	2.063269
Prob (F-statistic)	0.000855		

Conclusion

- The **flood peak flows** are a major contributing factor to the kinds of damages analyzed.
- Prolonged **flood duration** negatively affects human **lives**, **houses** and **crop area**. However its impact on livestock is statistically insignificant.
- **Awareness** as proxied by **adult literacy** is empirically determined to have a **negative relation** with damages. High literacy and awareness can help reduce damages to human lives, crop areas and houses. People do timely **respond on early warning systems** and take precautionary measures with high literacy rates.
- **Population density** has a significant positive correlation with loss of human **life** and destruction of **houses**. A greater concentration of population in flood prone areas can increase the risk of life loss and house damage as well.
- Government's **expenditure on embankments** has not helped in reducing the damages to lives, houses, crops and livestock. The main purpose of flood embankments is to sustain irrigation infrastructure during floods.

Policy Recommendations

- Water structures such as **dams** and **barrages** should be constructed up stream to regularize flood flows.
- Along with development of water infrastructure, f**loodwater drainage plans** may also be developed to reduce the flood duration.
- There is need of the hour to focus on **promoting literacy rate** along with flood **awareness programs** in Punjab.
- Population settlements should be restricted in the flood prone areas of Punjab, by the responsible agencies.
- The water bureaucracy of Punjab should give attention to **reorient flood embankment expenditure** pattern.
- **Flood resilient agriculture practices** should be promoted and the use of **flood resilient crops** should be incentivized by the stakeholders.

- Incentives should be provided to promote **flood resilient housing** and **infrastructure** so that infrastructure losses could be minimized.
- Basin wide **integrated flood management framework** should be developed to forecast, estimate, manage and develop flood resilience.
- There should be **implementation of land laws** that would prevent people to develop settlements in the flood plains.
- Government agencies should focus on a **pro-active approach** to flood prevention so that the losses can be reduced.
- In future hydrologic and hydro economic models for each river in the Indus Basin should be developed so **that significant flood impact parameters** could be **identified** and used in further research.

Thank you