FIG WORKING WEEK 2019

22–26 April, Hanoi, Vietnam

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"Geospatial Information for a Smarter Life and Environmental Resilience"

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Regional Indirect Economic Impacts of Wildfire Damages on Regional Economy

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Contents

- Background
- Literature Review
- Analysis and Simulation
- Result and Further Research Issues

Background(1)

- **Wildfires have negative impacts on ecological biodiversity, personal health, commodity flows and regional imcomes.**
  - The 1997-1998 Wildfire in Indonesia (including Sumatra) : 16.6 billion $, 12 million ha
  - The 2008 wildfire in California: burned area of 17,582 ha (400 houses, 500 mobile homes)
  - The wildfires of EMA in Korea : 973 ha(1996) / 23,794 ha(2000) / 973 ha(2005) / 1,757 ha(2019)

1997-1998 Wildfires in Indonesia

2019 Wildfires of EMA in Korea

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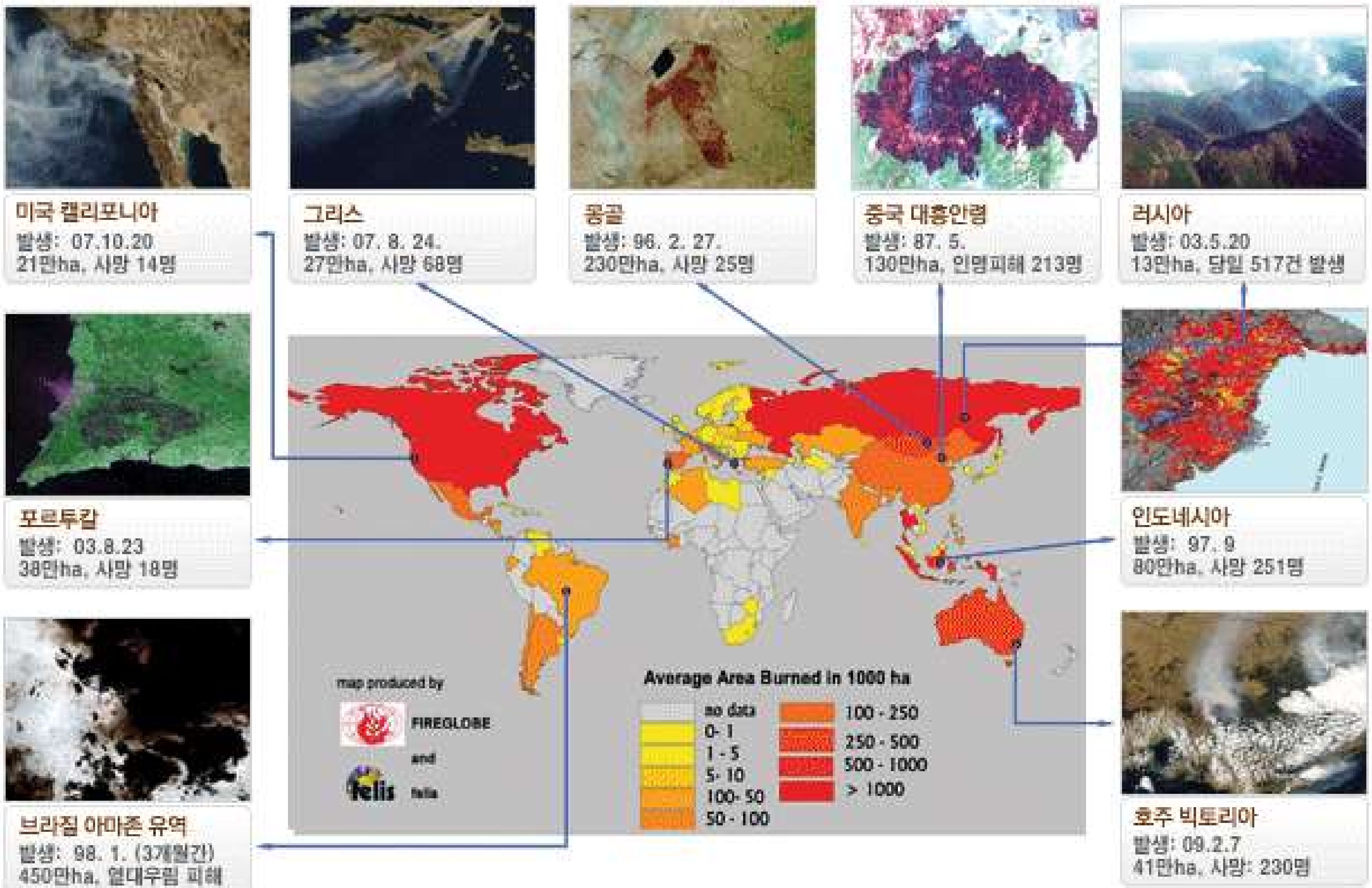
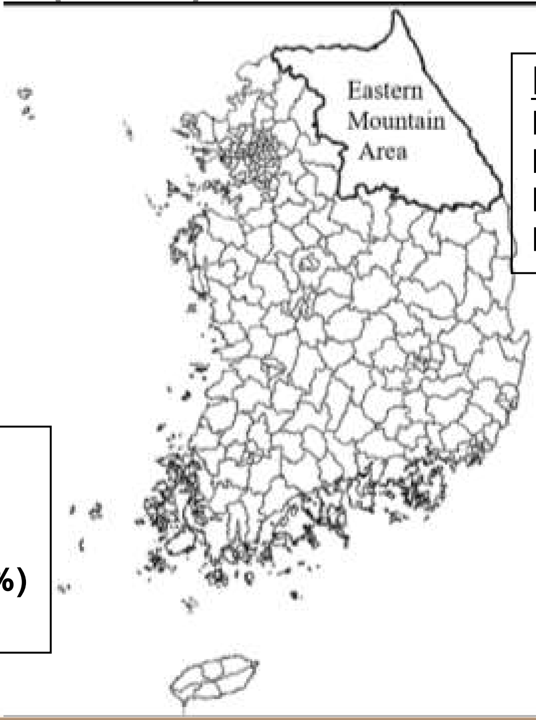


Background(2)

- **64.2% of total national lands covered with mountain and forest areas in Korea.**
  - Eastern Mountain Area (82.1%)



Eastern Mountain Area (EMA)
Pop. : 1.54 million person (3.0%)
Land area : 1.68 million ha(16.8%)
Forest : 1.38 million ha (82.1%)
Pop density : 88.2 pop/㎢

South Korea
Pop. : 50.95 million person
Land area : 10.01 million ha
Forest : 6.43 million ha (64.2%)
Pop density : 485.6 pop/㎢

Background(3)

- The fire frequency tends to further increase due to the climate change.
  - Drier conditions would result in increases in the frequency of extreme events and fire activities across the U.S. by 2050 using NASA satellite data and climate (Giglio *et al.*, 2012) .
- It is worthwhile to develop an analytic framework for the impact analysis.
  - To provide a guideline for the allocation of financial resources of government in terms of precautionary and rehabilitation activities.
  - To consider **"Fire management Drone"** system in series of wildfire management policy

Background(4)

- **The purpose of this study is to estimate economic impacts of wildfire damage on regional economies, developing an Integrated Disaster-Economic System (IDES).**
  - (1) Interregional Computable General Equilibrium (ICGE) model
  - (2) Bayesian Wildfire model
  - (3) Transpiration Demand model
  - (4) Tourist Expenditure model

Literature Review (1)

- **To measuring regional impact of nature disasters including wildfires.**
  - Type of disasters: Earthquake, Typhoon, Facility and service disruption (power plant, water supply), Sea level rise
  - Type of methods: Regression model, Cost analysis, Input Output model, CGE model
- **Not easy to measure effects by disaster on regional economies due to the innate complexities and uncertainties.**
  - Uncertainty : size of disasters
  - Potential double counting problems : industrial classification
  - Ambiguity : supply or demand, exogenous or endogenous variable
  - Unexpectedness : behavioral patterns of households and firms after fires
  - Assumption : outcome of analysis depends on initial assumptions.

Literature Review (2)

Impact Analysis of Disasters

Author	Type of Disasters	Model	Impacts / Key Issues
Rose *et al.* (1997)	Earthquake	IO model and Linear programming	Reduction in the GRP by 7%
Cho *et al.* (2001)	Earthquake	IO model	Integration of network model, spatial allocation model and the IO model
Kim *et al.* (2002)	Earthquake	IO model	The IO model combined transportation model
Sohn *et al.* (2003)	Earthquake	IO model	Network effects on transportation
Okuyama (2004)	Earthquake	Sequential inter-industry model	Impacts on inter-regional and inter-industrial sectors
Rose *et al.* (2005)	Disruption in water service	CGE model	Impacts of water service disruptions
Bosello *et al.* (2007)	Sea level rise	CGE model	Impacts on the GDP and energy consumptions
Tatano and Tsuchiya (2008)	Earthquake	Spatial CGE model	Direct and indirect spillover effect on regional economies
Ryu and Cho (2010)	Typhoon and heavy Rain	IO model	Reduction in the GDP by 1.18%
In den Baumen *et al.* (2015)	Flood	MRIO model	Indirect loss of production €6.2 billion
Baghersad and Zobel (2015)	Disasters	New linear programming model with IO system	Indirect economic impacts of disasters
Koks and Thissen (2016)	Floods	IO model	Supply driven regional IO model with transport disruption
Husby and Koks (2017)	Disasters	The IO and the CGE model with ABMs	Integration of micro model with the IO and the CGE model

Literature Review (3)

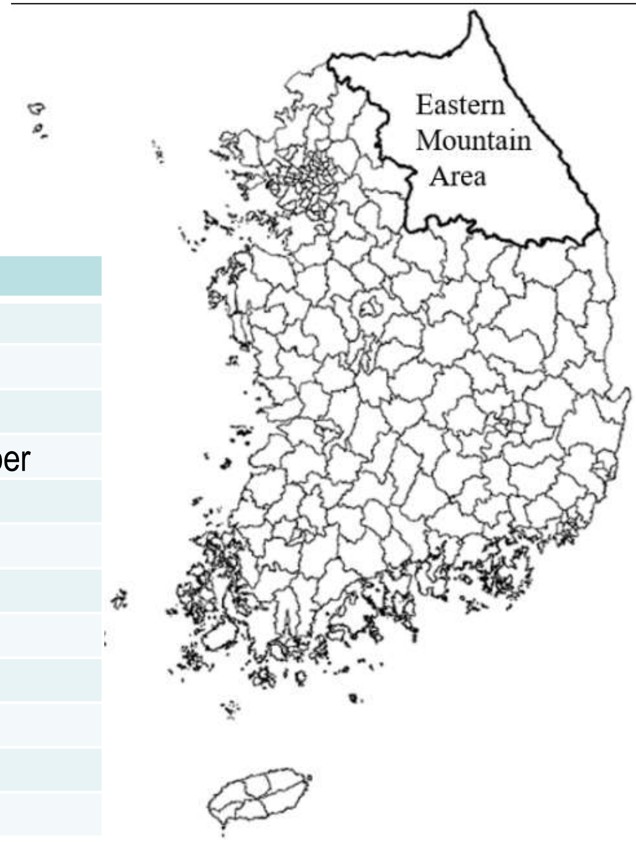
Impact Analysis of Wildfires

Author	Region	Method	Impacts / Key Issues
Mercer *et al.* (2000)	USA / Florida	Spatial and Econometric Analysis	1864 US$ per acre of economic losses
Kunji *et al.* (2002)	Indonesia	Econometric Analysis	Change in mortality
Rahn (2009)	USA / California	Cost Analysis	2.45 billion US$ of costs
Moseley *et al.* (2012)	USA/ California	Econometric Analysis	Increases in local employment and wages
Kiel and Matheson (2015)	USA / Colorado	Econometric Analysis	Decline of housing sale price by 21.9%
Kochi *et al.* (2016)	USA / California	Econometric Analysis	3.4 million US$ of medical costs
Pyke *et al.* (2016)	Australia	Cost Analysis	1.5 million US$ of post-fire flooding costs
Sage and Nickerson (2017)	USA / Montana	Cost Analysis	240.5 million US$ of visitor spending losses

Analysis (1)

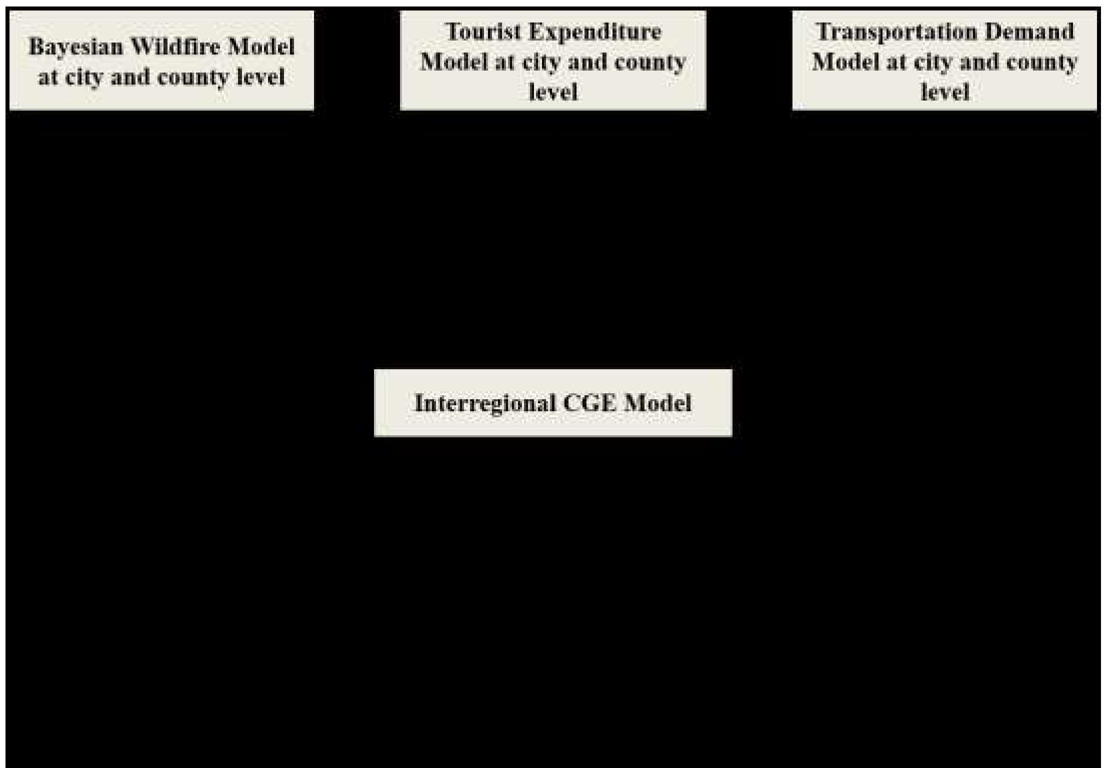
- Two Regions in South Korea
  - Eastern Mountain Area, Rest of Korea
- Industrial Classification of 12 sectors

Classification	Sub-Sector
Forest sectors	1. Forest Products
	2. Wood and wood products
	3. Pulp and paper products
	4. Other manufacturing products and processing of timber
Tourism sectors	5. Retail and wholesale services
	6. Transportation services
	7. Restaurants and accommodation services
	8. Cultural Services
	9. Sports and entertainment services
General sectors	10. Primary Industry
	11. Manufacturing Industry
	12. Service Industry



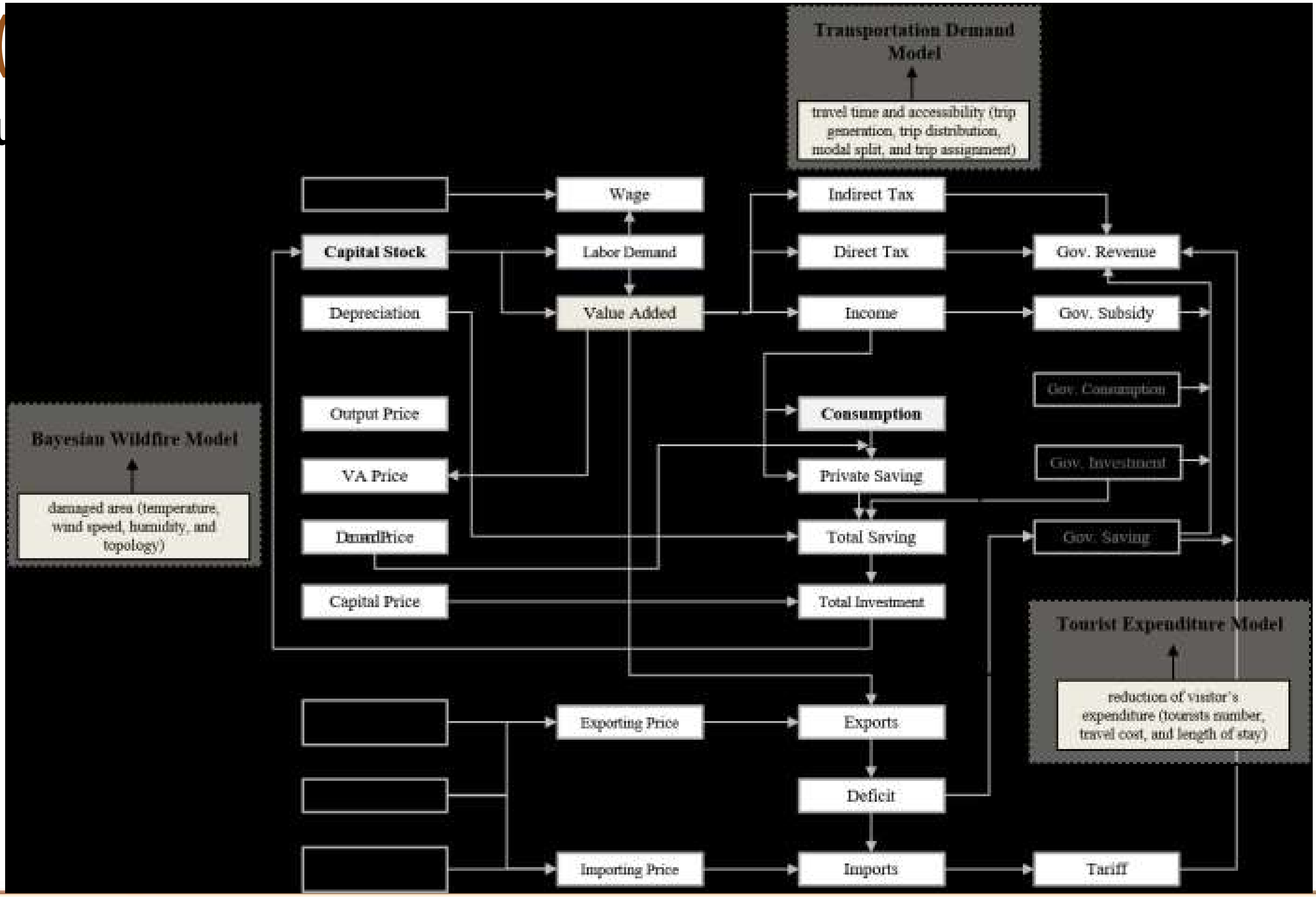
Analysis (2)

- **Structure of Integrated Disaster-Economic System**



Analysis (

- **Structu**



Analysis (4)

- **Major Equations of Interregional CGE model**

Output	**Output = Leontief (Value added, Intermediate demand)**
Value added	Value added = Total Factor Productivity*CD (Capital stock, Labor, Land)
Supply	Output = CET (Foreign exports, Domestic supply)
Domestic supply	Domestic supply = CET (Regional exports, Intraregional supply)
Demand	Demand = Armington (Foreign imports, Domestic demand)
Labor demand	Labor demand = LD (Wage, Value added, Net price)
Total Factor Productivity	Total Factor Productivity = TFP (Accessibility, Population)
Labor supply	Labor supply = LS (Labor market participation rate, Population)
Population	Population = Natural growth of population + Net population inflows
Regional incomes	Regional incomes = Wage + Capital returns + Government subsidies
Migration	Migration = TODARO (Incomes and employment opportunities of origin and destination, Distance between origin and destination)
Consumption	Consumption by commodity = CC (Price, Incomes)
Private savings	Private savings = PS (Saving rate, Income)
Government revenues	Government revenues = Indirect tax + Direct tax + Tariff
Government expenditures	Government expenditures = Government current expenditure + Government savings + Government investment expenditure + Government subsidies
Labor market equilibrium	Labor demand = Labor supply
Capital market equilibrium	Private savings = Total investments
Commodity market equilibrium	Supply of commodities = Demand for commodities
Government	Government expenditures = Government revenues

Analysis (5)

Analysis (6)

- **Transportation Demand Model**

$$T(OD) = \sum_{k=1}^{n} lt(OD)_k \qquad (l(OD) \in p(OD))$$

T(OD): travel time from origin to destination
lt(OD): travel time of link l(OD)
l(OD): links in p(OD)p(OD): the shortest line from origin to destination
O, D: origin and destination
n: the number of links in line p

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Analysis (7)

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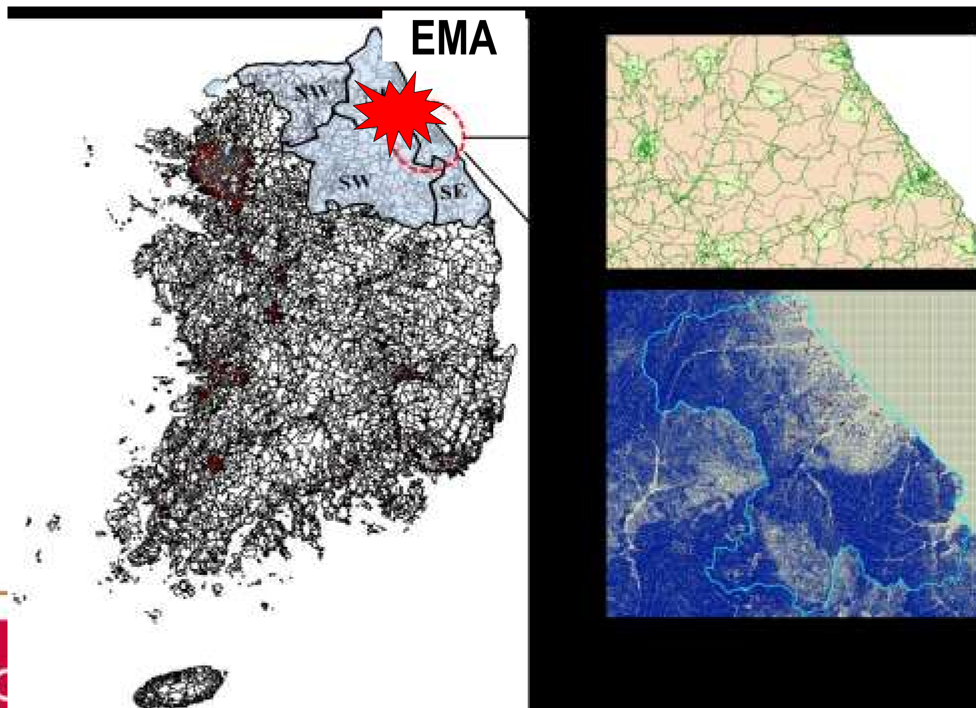
Simulation(1)

- **Wildfire Damaged Area derived from three external shocks**
  - (1) **Wildfire damaged area** from Bayesian wildfire model
  - (2) **Changes in travel time** due to the wildfire from transportation demand model
  - (3) **Decrease in visitor's expenditure** derived from tourist expenditure model



Simulation (2)

- **Wildfire Damaged Area by Weather Condition under W/, W/O Climate Change**
  - Results of Monte Carlo Simulations of a combination of lower and upper levels of three stochastic variables (temperature, average wind speed and relative humidity distributions)

Scenario	Without Climate Change		With Climate Change(RCP8.5)		Weather Condition		
Cases	Lower limit	Upper limit	Lower limit	Upper limit	Temperature	Wind Speed	Relative Humidity
1	55.3	62.7	80.0	87.0	Lower	Upper	Lower
2	53.7	60.9	74.9	81.7	Lower	Lower	Lower
3	51.9	59.0	69.8	76.5	Lower	Upper	Upper
4	57.8	65.3	82.0	88.7	Lower	Lower	Upper
5	53.7	60.9	74.9	81.7	Upper	Upper	Lower
6	52.3	56.5	69.0	73.8	Upper	Lower	Lower
7	49.2	54.0	66.9	72.1	Upper	Upper	Upper
8	45.8	51.4	64.8	70.4	Upper	Lower	Upper

Simulation (3) Coding

- GAMS

Simulation (4) Result

- **Economic Impacts of Wildfire on VA(Value added) and GRP(Gross Regional Product) of EMA**

	Without Climate Change			With Climate Change (RCP8.5)		
	Lower	Mean	Upper	Lower	Mean	Upper
4 Forest Sectors*	-12.116	-14.750	-17.425	-17.425	-20.020	-23.114
5 Tourism Sectors**	-0.767	-0.740	-0.846	-0.854	-0.990	-1.386
Primary Sector	-0.017	-0.047	-0.119	-0.148	-0.178	-0.623
Manufacturing Sector	0.017	0.077	-0.112	-0.174	-0.206	-0.753
Service Sector	0.187	0.048	-0.088	-0.012	-0.419	-0.702
GRP of EMA	-0.249	-0.371	-0.548	-0.511	-0.836	-1.232
GRP of ROK	0.002	0.002	0.005	0.000	0.014	-0.014
GDP (Total GRP)	-0.003	-0.006	-0.006	-0.010	-0.004	-0.040

Reflex gains in ROK

0.263%p ~ 0.648%p

Conclusion

- **Consumption of EMA & ROK residents on Goseong decrease 5.78% & 6.07% respectively**
- **GRP of EMA decline**
  - By 0.249% to 0.548% without climate change / 0.511% to 1.232% with climate change (CC) → The climate change lead to magnify economic loss from 0.263% to 0.684%.
- **Average damage area under CC could increase 40.4%, compared to without CC**
  - Wildfire decrease VA in forest (12.116%~17.425%) & tourism sectors (0.767%~0.846%)
- **GRP of ROK increase by 0.002%~ 0.005% under the without CC → ROK has reflex gains**
  - GDP decline by 0.003%~0.005% without CC, but 0.001%~0.040% under climate change

Limitation of the study

- Spatial diffusion pattern of wildfire need to be examined at city and county level
- Focus more on dynamic analysis for interactions and spillover effects among environment and economic agents
- Improving fire occurrence probability model with spatial point processing method

Further Research Issues(1)

- Regional economic resilience to bounce back
  - Diversification strategy on industrial mix and tourism spending mix
- Implement regional coordination and rehabilitation program
  - Developing dark tourism products & travel route for the damaged areas by disaster
  - Increasing tourism income of on-site & promoting wildfire prevention policy
- Utilizing drone and video control equipment in forestry research and practices by **LX**
  - Due to its flexible, low-cost, and high-resolution of drone(Tang and Shao, 2015)
  - Improving Korean wildfire management system in a series of process of the early detection of wildfire, rapid suppression and even the recovery step.

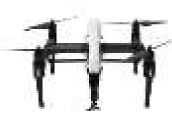
Furder Research Issue(2)

- On the policy side
  - Dark tourism products → Minimizing the amount of tourism spending reduction and utilizing it as a new regional financial revenue source
  - LX drone development
    - special mission series for first action of wildfire, cleanup wildfire using thermal imaging sensor, hazardous gas measurement

Fire Management Drone System

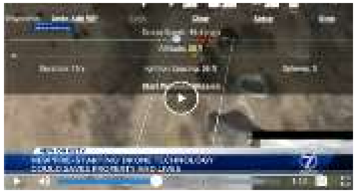
Real time transmission of Forestry data
(fuel, slope, temperature, humidity, wind speed, etc)

LX Drone



Precaution &First action against wildfire

- Tracking spread path of wildfire
- Guiding evacuation route & shelter
- Constructing firebreaks(lines & lanes)



Regular monitoring system

- Detecting flying sparks
- Rapid suppression on inaccessible fireplaces

Post-fire detection

- Thermal imaging sensor

Collecting harmful gas

- Wildfire emissions
- Air quality control (travel distance)

Thank you!