VALUING AND INSURING NATURAL ASSETS: CHALLENGES & OPPORTUNITIES

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Measure what is measurable and make measurable what is not so.

---- Galileo Galilei

Resilience is the capability (of individuals, properties, infrastructures, companies, communities, or governments) to withstand & recover from *disasters,* as well as learn from past disasters to strengthen future *response* and *recovery* efforts.

TRENDS IN NATURAL CATASTROPHE LOSSES (SWISS RE, MARCH 30, 2022)

- Average annual losses are USD 220 billion from 2011 to 2021
  - Primary (low frequency, high severity) perils are worsening: Hurricanes/typhoons (wind, flood), earthquakes (shaking ground, tsunami), winter storms
  - Increasingly secondary (medium-low frequency, medium severity) perils driving losses: Wildfire, drought, heatwave, torrential rain, landslide, coldwave, snow, hail
  - Average annual natural catastrophe protection gap (economic losses not covered) averaged USD 139 billion
- 2021 economic losses of USD 270 billion with a protection gap of USD 159 billion
  - 50 severe flood events; Economic losses more than USD 80 billion; Protection gap was USD 60 billion
  - Upturn in flood-related insured losses in last 20 years driven by …

1. Accumulation risk driven by urbanization and economic growth
2. Climate change
3. Aging infrastructure
4. Lack of flood control infrastructure (e.g., “soil sealing”)

Exposing the Hidden Risks in the Built Environment

Traditional Direct Risks:
Direct Facility Damage

Only Direct Damage to Property

Dependency Risks: **One Concern** is the only market player that identifies and quantifies dependency risk - the risk from the surrounding infrastructure ("lifelines") that businesses depend on which account for the majority of the physical risk

Values ($BN)

Power Grid Damage | Road Damage | Port Damage | Airport Damage | Bridge Damage | Community Damage

Highly-Connected Properties Face a Multitude of Dependency Risks due to Damages to Surrounding Infrastructure

Next Gen Risk Technology Platform that Integrates Complex Physical, Natural, and Financial Information

1C Digital Twin of the physical world with **8T data points in the US today** – more than most governments or utility companies

Physical infrastructure layer

Atmospheric data
Infrastructure data
Asset footprint data

External **catastrophe models "break" the digital twin,** and generate resilience metrics from ripple effects in the form of "business downtime"...

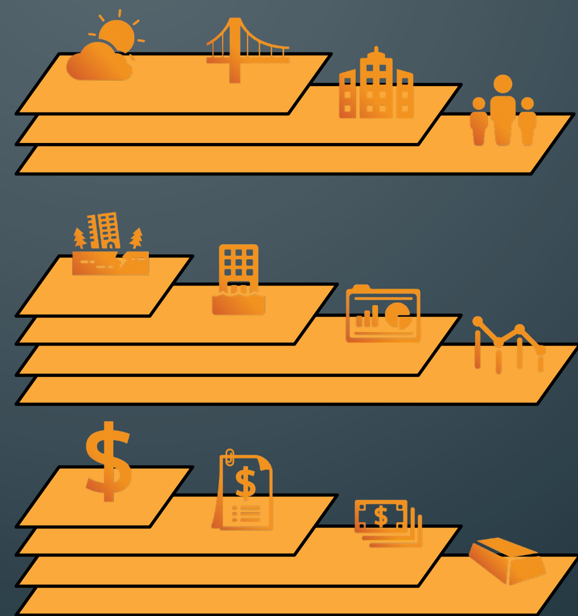
Risk exposure layer

Seismic models
Flood models
Risk portfolio data
Historical loss data

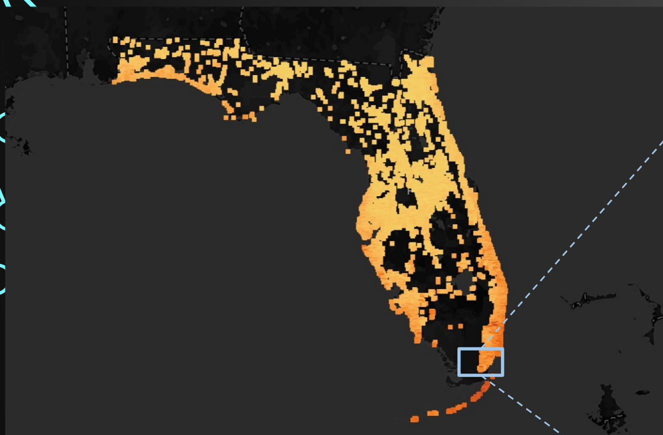
...which integrates seamlessly with existing risk / valuation frameworks, paving the way for the very first time, to **measure cash flow impairments** in a consistent and comparable way.

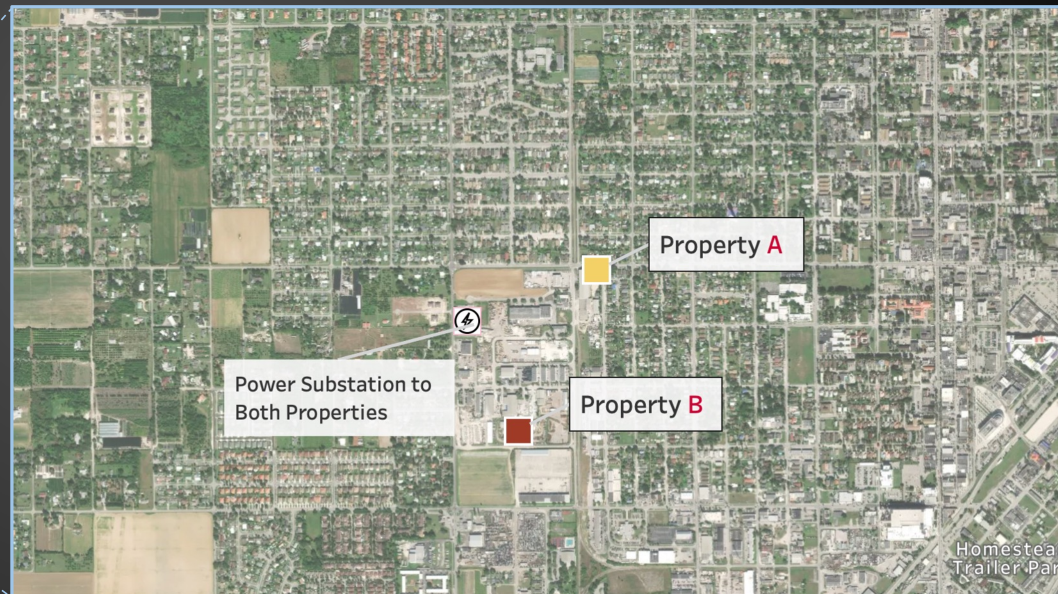
Financial layer

Interest rates
Exchange rate
Wage index
Commodity prices



1C Risk Technology Platform

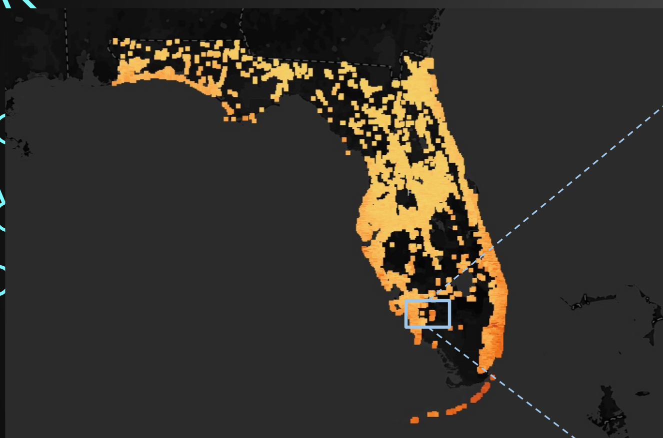


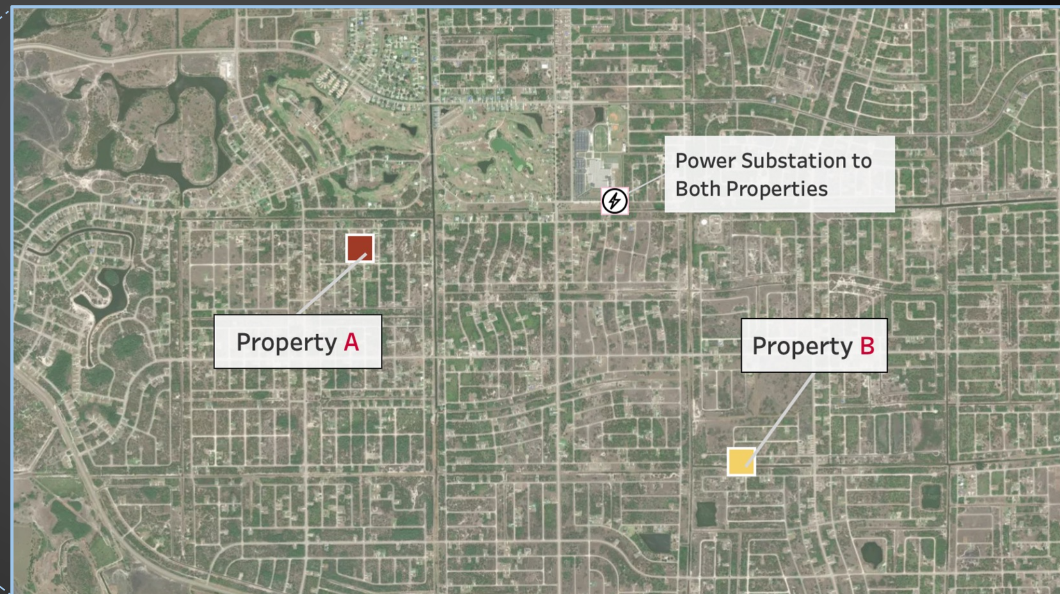


Example

Two properties located within 0.35 miles of each other are connected to the same power substation. Property A experiences 23.46 days of downtime while Property B experiences 53.98 days of downtime due to 250 year wind and flood events. The reason is the power line that connects Property A to the substation is of higher priority for restoration due to higher importance.

	Policy key	Loc nbr	Address	Lifeline downtimes over the 250 year return period (days)					
				Power	Community	Highways	Ports	Airports	Integrated
Property A	160634	3333	950 NW 8th ST, HOMESTEAD, FL, 33030	**15.27**	126.13	1.2	22.35	2.22	**23.46**
Property B	160634	4572	1225 NW 2 ST., HOMESTEAD, FL, 33030	**66.3**	125.13	1.2	22.35	2.22	**53.98**





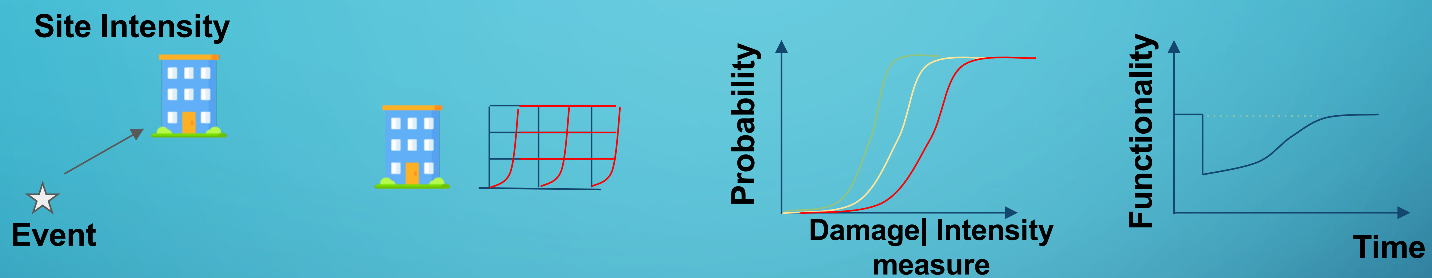
Example

Two properties located within 1.7 miles of each other are connected to the same power substation. Property A experiences 34.01 days of downtime while Property B experiences 12.36 days of downtime due to 250 year wind and flood events. The reason is the power delivery to Property A is through overhead lines while Property B gets power from underground lines. The underground lines are not vulnerable to the wind peril.

	Policy key	Loc nbr	Address	Lifeline downtimes over the 250 year return period (days)					
				Power	Community	Highways	Ports	Airports	Integrated
Property A	160035	293	710 FULLERTON AVE S, Lehigh Acres, FL, 33974	**52.47**	22.43	0.88	0.0	2.06	**34.01**
Property B	160404	3016	935 CANDLELIGHT DR., LEHIGH ACRES, FL, 33936	**15.66**	26.92	0.84	0.0	2.06	**12.36**

Physics-based/machine-learning resilience modeling

Fragility or vulnerability functions created for resilience modeling



Hazard Analysis	Structural Analysis	Fragility Analysis	Recovery Analysis
• Hazard • Perils • Building Inventory	• Obtain structure responses under different hazard intensities	• Generate fragility curves from responses • Probabilities of damage levels	• Recovery functions of damage level • Combine with fragility curve to identify recovery trajectory given a hazard intensity

EUR 510 bn or 36% of EUR 1.4 Dutch investments affected by Ecosystem Services (ESS). (DNB, 2020)

VALUABLE CORAL REEF ALONG 60KM STRETCH OF MEXICO'S YUCATAN PENINSULA' COASTLINE

- Mexico's Caribbean coast was struck by two hurricanes in 2005 causing USD 8bn in damages with continuing economic damage in Cancun
- A few hotels and beaches in Puerto Morelos suffered less damage than others in the state of Quintana Roo attributed to an intact coral reef
- 97% of wave energy is estimated to fall when blocked by a healthy coral reef. Losing the top 1 meter of an existing coral reef is estimated to double expected damages from flooding.
- Tourism industry generates USD 10bn in the Quintana Roo area

Nature Conservancy, "Insuring nature to ensure a resilient future," global.nature.org, 2018

Beach in Mexico

OUTLINE

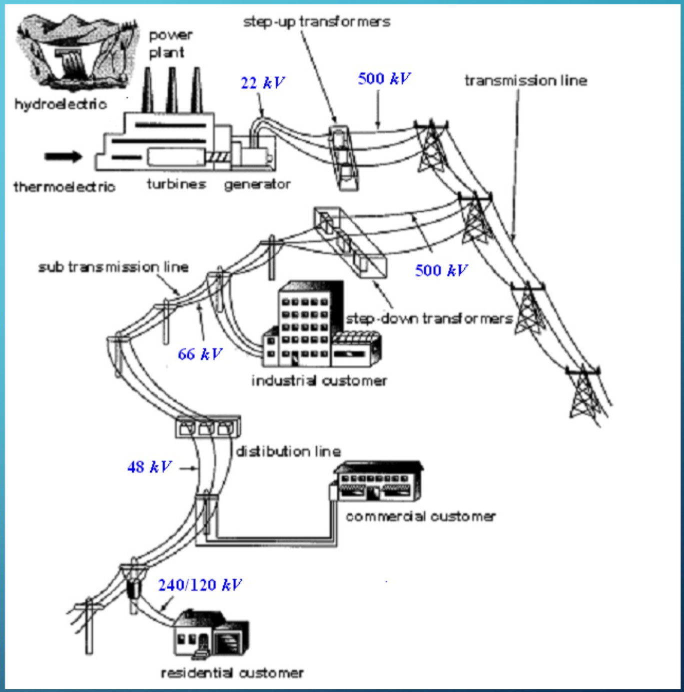
1. Trends
2. Valuation
3. Insurance
4. Valuing and insurance of natural assets – three case studies
   a. a) Coral reefs
   b. b) Aquaculture
   c. c) Forests
5. Resilience bonds
6. Discussion

BACKGROUND TRENDS

Resilience depends not only a property's structural integrity, but also on the robustness of lifeline networks (LLN)

- LN, which when disrupted, impair function:
  - Power
  - Transportation
  - Residential communities
  - Telecommunications
  - Supply chains
  - Water
  - Wastewater
  - Stormwater
  - Gas and liquid gels
  - Solid Waste

- Challenges
  - Interdependency among different systems (*networks)*
  - Incomplete data (*synthetic data generation)*



Example: Power grid consists of generation, transmission, and distribution systems

ECOSYSTEM SERVICES (ESS) (LIST BASED ON SRI BES INDEX, 2020)

- Habitat intactness (Biodiversity, reefs)
- Pollination
- Air quality & Local climate
- Water security
- Water quality
- Soil fertility
- Erosion control
- Coastal protection
- Food provision
- Timber provision

PRIVATE VS PUBLIC GOODS

Category	Service flow characterization
Pure private	Typically exchanged in normal markets, exclusive consumption, rivalry of consumption (once consumed, can't be resold) (e.g., fossil fuels)
Quasi-private/public (= theory of clubs / club goods)	Typically not exchanged on markets, semi-exclusive consumption (e.g., recreational fishing, game resorts with entry fee)
Pure public	Not exchanged on markets, non-exclusive, non-rival consumption (e.g., biodiversity, national parks open to public, clean air/water)

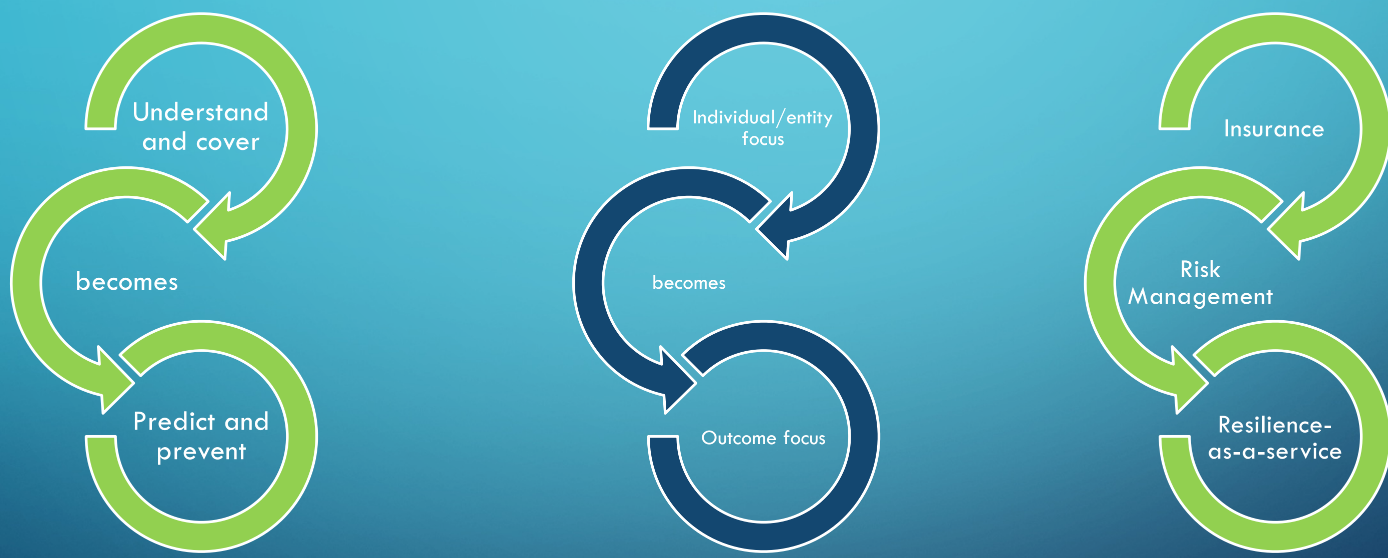
Kopp, Raymond J. and Kerry Smith, eds., 1993, *Valuing natural assets*, Resources for the Future, *Washington D.C.*

MULTIPLE TRENDS CONVERGING

TACKLING FUNDAMENTAL PROBLEMS & REALIZING THE POTENTIAL OF INTERNET OF THINGS (**IOT**), **5G**, MACHINE INTELLIGENCE (**MI**), & DISTRIBUTED LEDGER TECH (**DLT**)

- Transition to a digital society of MI & humans living together
- Global trading & supply chain digitization Facilitated with IoT & DLT
- Living longer and democratization of Health from Labs to Wearables
- Climate change & natural resources Managed for resilience & sustainability

SHIFTS IN THE INSURANCE INDUSTRY



VALUING NATURAL ASSETS

APPROACHES TO VALUING NATURAL ASSETS

- Lost-use value directly related to valuable commerce
- Lost-use value related to public use
- Option (contingent) value
- Replacement cost
- Restoration cost
- Hedonic pricing (use composite goods)
- Value added to marketable goods
- Preassigned value associated with public utility
- Willingness to pay (infer utility functions using surveys)

- Simulation methods

VALUING NATURAL ASSETS

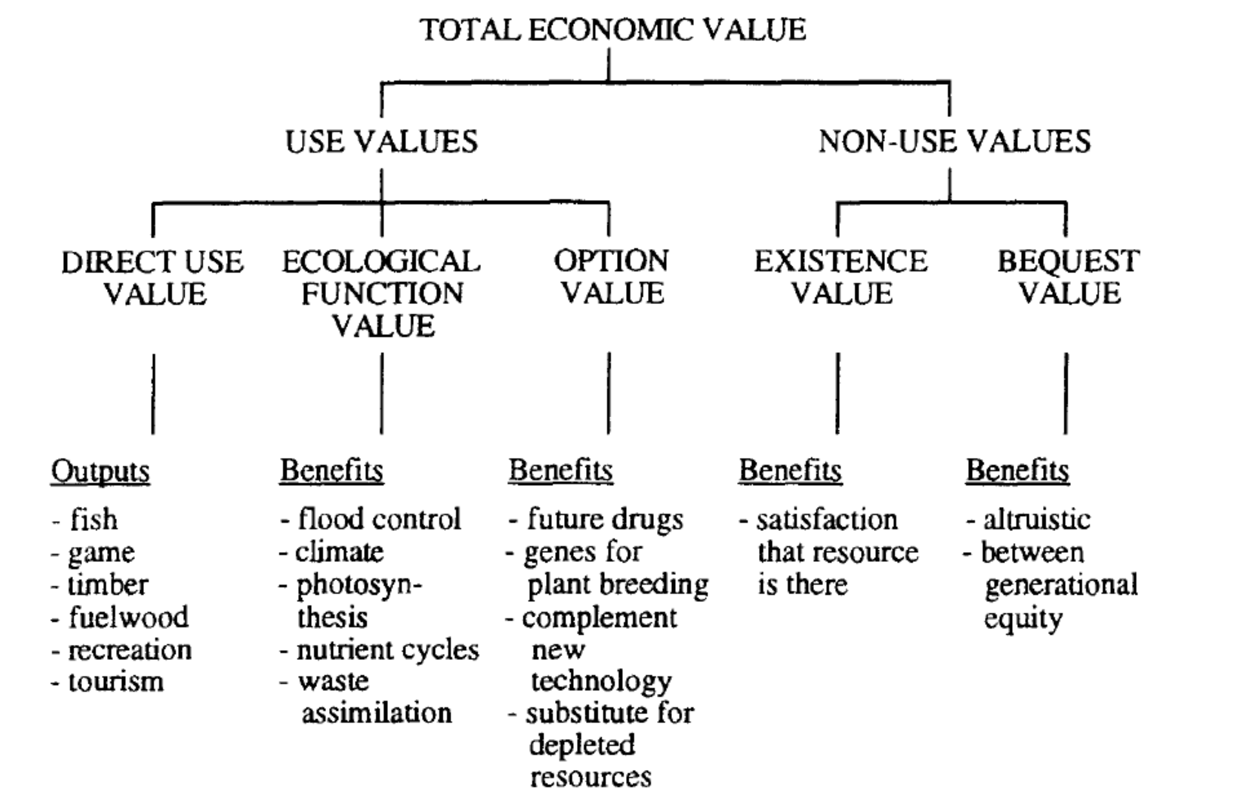


Fig. 1. The nature of total economic value (Young, 1992; after Barbier, 1991).

MODIFYING DISCOUNTED-CASH-FLOW (DCF) MODELS

- Develop models for exceedance probabilities i.e., Probability that system is in an impaired state
- Complement with models for **downtime** conditional on ending up in the impaired state
- Challenge lies in collecting data and calibrating a model
- Synthetic data generation

INSURING NATURAL ASSETS

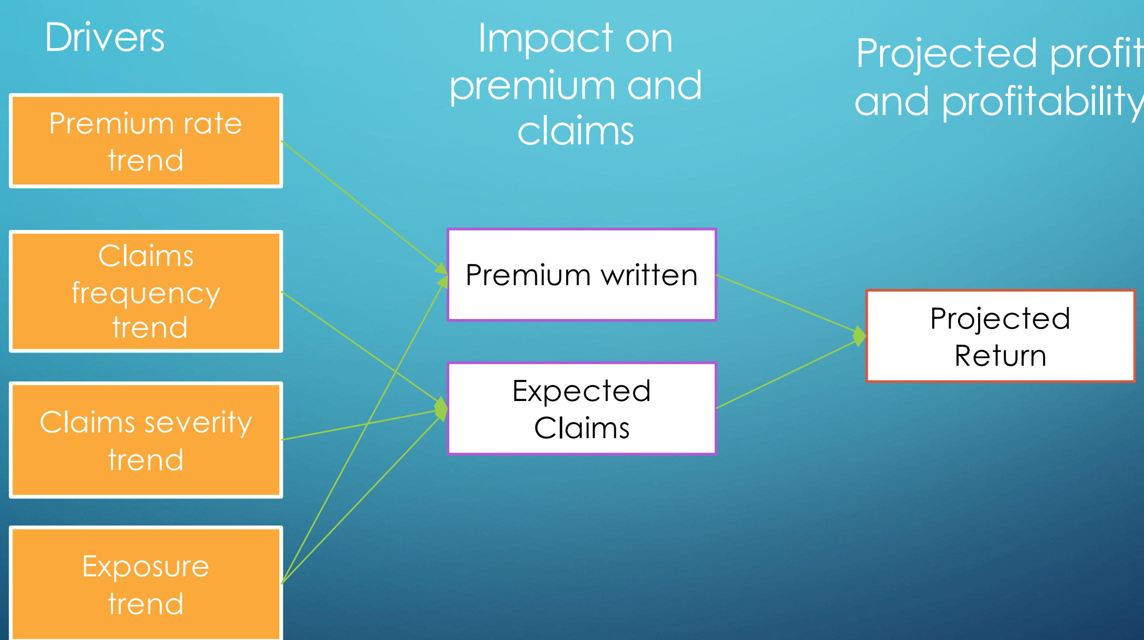
CATASTROPHE INSURANCE: HAZARDS & PERILS

- Earthquake
  - Shaking ground
  - Tsunami
  - Liquefaction
- Hurricane/Typhoon
  - Flood inundation
  - Wind
  - Landslides
- Severe convection storms
- Other
  - Hail
  - Pollution
  - Cyber attack
  - Physical attack
  - Explosions

Re/insurance accomplishes three objectives:

Prices risk	Provides a financial safety net	Creates incentives to improve behaviour
		

FORECASTS ARE NEEDED FOR 4 DRIVERS FOR EACH INSURANCE PORTFOLIO SEGMENT (IPS)



CONDITIONS FOR INSURABILITY

1. Ability to quantify *frequency* and *amount (severity)* of loss related to different levels of insurance coverage
2. Ability to set *premiums* for potential customer or class of customers that reflect the covered risk for a given level of coverage
3. Ability to earn positive expected profit by providing coverage against covered risk– premiums must also cover development and marketing expenses
4. Ability to avoid asymmetric information & "lemons" (i.e., only worst risks are covered) problems– loss events are not predictable and diversified across a suitably large portfolio

Heal, Geoffrey and Howard Kunreuther, "Environmental assets & liabilities: Dealing with catastrophic risks," November, 2008, Working paper#2008-11-06, The Wharton School, University of Pennsylvania.

REINSURANCE PRICING

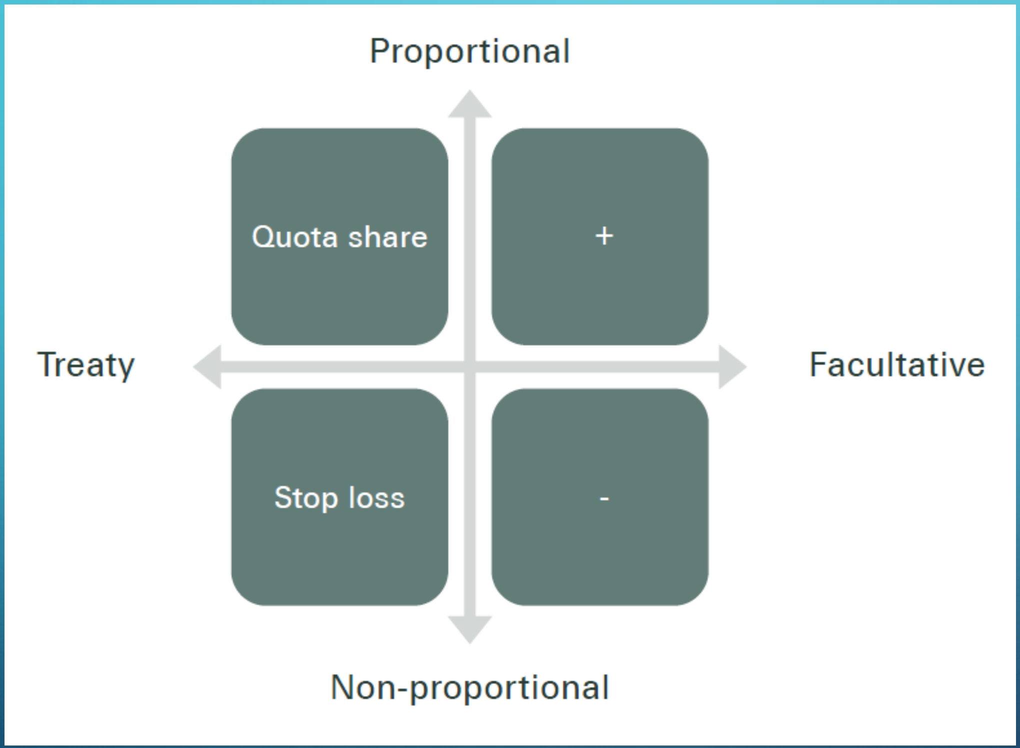
Exposure pricing

- no individual loss experience available
- based on:
  - market loss experience
  - covered hazards / perils
  - country specific conditions (e.g., diseases)
- ILF (increased limit factor) curves
- ROC considerations
- loss scenarios considerations
- individual risk judgment: below or above market average?

Experience pricing

- individual loss experience and corresponding exposure data available
- as-if considerations with respect to loss history (change of portfolio, environment, technical processes/equipment): are past losses still representative in today's environment?
- based on experience: calculate individual risk profile
- take into account future trends/developments
- price unused layers

TYPICAL REINSURANCE STRUCTURES



TETRALEMMA-BASED CHALLENGES FOR PARAMETRIC INSURANCE & RESILIENCE BOND DESIGN

Correlated

Links closely to actual financial loss

Compre-hensive

Characterizes full range of relevant indicators & damage

Objective

Resists tampering and manipulation

Profitable

Facilitates timely, cost-effective, sellable coverage

NEW DATA SOURCES

- Unstructured data from e-mail interactions, court cases, or other textural sources
- Qualitative data available by segment
- Synthetic data generated from otherwise unusable (e.g., too-rare-events, data privacy reasons) granular data

NEW TIME-SERIES PREDICTION ALGORITHMS

- New causal inference tools
- Meta-learning using projective simulation
- Reinforcement learning
- Gradient boosting
- Generative adversarial networks (GANs)
- Quantum-inspired evolutionary AI
- Optimal prescriptive trees

GENERAL MODELING CHALLENGES

- Variable data availability & quality; time series not long enough to build usable loss history
- Changing underlying data generation processes induces non-stationarity
- Moving up the ladder of causation (Pearl, 2018, p. 28)
  - Level 1: Association (Seeing, observing)
  - Level 2: Intervention (Doing, intervening)
  - Level 3: Counterfactuals (Imagining, retrospection, understanding)
- Macroeconomic interaction
- Insurance market interaction (Game theory)
- Behavioral economics (Changing product design, marketing, distribution, strategy can change opportunities within a given segment)
- Digitizing society impact

NATURAL ASSET INSURANCE

- Identify natural assets that provides substantial economic value: Reefs, mangrove swamps, urban forests
- Eco-system services
- Find indicators that track value impairment (e.g., wind speed, flood levels, changes in chemical composition, volume of biomass, etc.)
- Develop parametric insurance with a payment trigger linked to objective and easily measured indicators (standard insurance is particularly difficult in this space)
- Public-private partnerships (governments, NGOs, private companies, insurance companies) are key to market development
- Future developments in the insurance-linked-securities (ILS) market could rapidly expand this kind of specialty insurance product
- Combine with predict-and-prevent services

WHAT MAKES NATURAL ASSETS HARD TO INSURE?

- Ambiguity of risk
  - Asset valuation can be difficult (flow values vs. stock values; real values vs. preferences)
  - Loss estimate can be difficult– catastrophic loss is always a concern
  - Probability of loss can be hard to estimate
  - Very often no loss history / no credible data about loss history
- Value of the natural asset or its ecosystem services to be insured
  - Boundaries of ecosystem services: what services are provided by / through the natural assets,
  - How is the value assessed
  - What is the value (and is it 'real' money flowing or only 'virtual' through stated preferences)
- Premium too high relative to potential customer demand
  - Ambiguity leads to multiple levels of uncertainty
  - Uncertainty leads to high premiums
  - Often, demand stems from individual agents, and there is no wider collective group insured
- Adverse selection
  - Premiums typically reflect average risk over a particular sample
  - Poor ability to distinguish "good" from "bad" risks can lead to the insurer taking on exposure primarily to "bad" risks leading to unprofitability
- Moral hazard
  - Policyholder behavior leads to increased probability of loss
  - Mitigants include deductibles and coinsurance i.e., risk-sharing arrangement

DRIVERS FOR PARAMETRIC INSURANCE

- Protect against economic loss
- Complements traditional insurance
- Cover underinsured or uninsurable risk
- Quick pay-out improves liquidity
- Pay-out can be used by the beneficiary for most urgent needs

COMPARING TRADITIONAL AND PARAMETRIC

Trigger	Loss or damage to physical asset	Event occurrence exceeding pre-defined threshold or trigger
Recovery	Reimbursement of actual loss sustained	Pre-agreed payment structure based on event parameter
Basis Risk*	Policy conditions, deductibles and exclusions	Correlation of chosen parameters and structure with actual exposure
Loss assessment and Payment	Months to several years – depending on complexity of loss	Very transparent and payment disbursement within 30 days
Term	Usually annual, multi-year difficult	Single or multi-year (up to three years)
Structure	Standard products and contract wordings	Customized product with high structuring flexibility (single trigger, multi-trigger)
Form	Insurance Contract	Insurance Contract

*Risk that Client's collected payout is not equal to the actual loss.

REEF COVERAGE EXAMPLE

- Identify a particular geometric area of coastal waters with a coral reef in place
- Assign payout as a function of the maximum intensity (measured in miles or kilometers per hour) of a hurricane measured within the geometric area defined in the contract; specify the following:
  - Wind speed
  - Time speed is sustained
  - Distance above the ground
- Trigger payment based on objectively measured maximum intensity in the specified geometric area

THREE CASE STUDIES

Coral reefs

Reef Insurance:
Fast-responding insurance policy that pays for rebuilding the reef while creating long-term incentives for investing in this natural protection

Aquaculture

Aquaculture Insurance:
Complex and vulnerable ecosystems require sensitive risk assessment

Forests

Forestry Insurance:
Largely untapped potential

CORAL REEF

TOURISM-RELATED REVENUE PER SQUARE KM OF CORAL REEF IS ESTIMATED AT USD 1MN TO 40MN. CORAL REEF TOURISM GENERATES USD 36 BN IN ANNUAL REVENUE.

(SPALDING, MARK, LAURETTA BURKE, SPENCER A. WOOD, JOSCELYNE ASHPOLE, JAMES HUTCHINSON, AND PHILINE ZU ERMGASSEN, “MAPPPING THE GLOBAL VALUE AND DISTRIBUTION OF CORAL REEF TOURISM,” *MARINE POLICY*, VOL. 82, PP. 104-113)

IMPORTANCE OF CORAL REEFS

- Highly diverse and productive ecosystem
- Protects large populations (840 m people live near reefs)

- Critical socio-economic resource in many countries
- Essential in developing countries
- Fisheries livelihoods and a primary source of protein

WHO DERIVES MONETARY BENEFITS FROM REEFS?

i.e. Who will get 'hit in the wallet' if reefs degrade?

Hotels/Resorts

Amenity

Homeowners

Protection

Ecotourism Inc.

Recreation

Fishers

Food

Direct Beneficiaries

Government

Indirect Beneficiaries

Universities

Education

NGOs

Inspiration

Images: Angsana Ihuru; SunsetHouse; Queensland.com; Vectorstock; AIMS; Alltournative

Reefs' Economic Value: Global=375bn

Provisioning Services
Food, genetic resources, etc

56K

+

Regulating Services
Erosion, waste treatment, etc

171K

+

Habitat Services
Nursery, genetic diversity, etc

16K

+

Cultural Services
Recreation, Education, etc

109K

Economic Value ($ ha^{-1} y^{-1})

De Groot et al. 2012; Reefproject

REEFS ARE UNDER THREAT


Temperature


Over-fishing


Nutrients

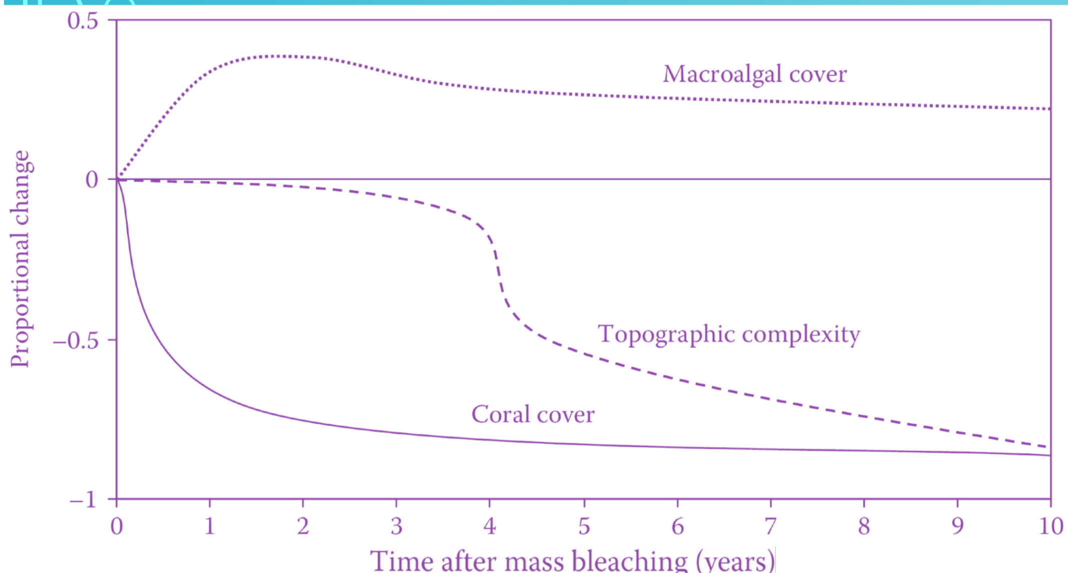

Sedimentation

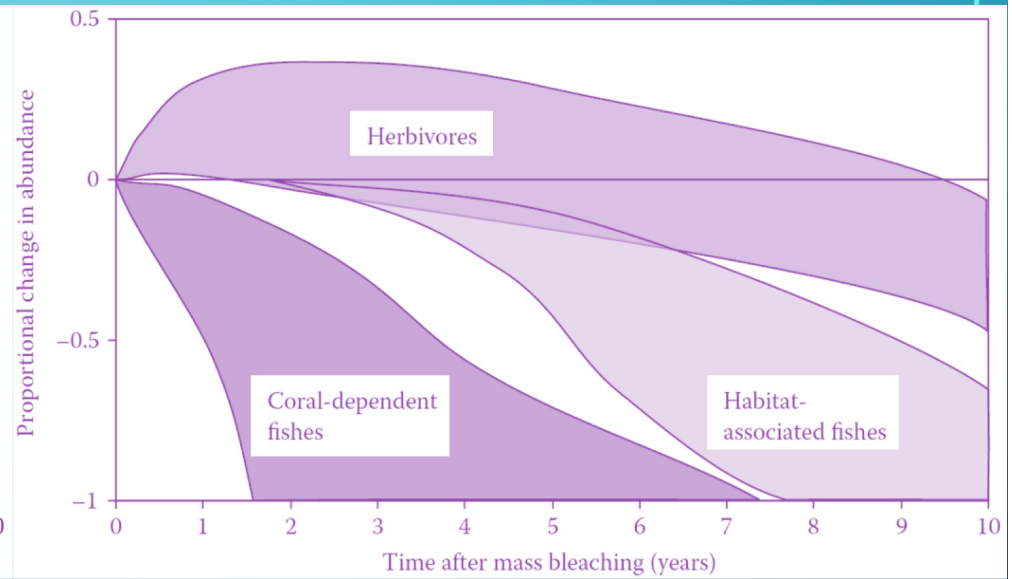

Hurricanes

- Stressors vary in their spatio-temporal scale and intensity
  - But ALL have capacity to reduce the monetary and other benefits provided by reefs

Images: Vardhan Patankar; Peter Vroom/NOAA; Grafner/istock; Katherine Chaston; Ethan Daniels

EXAMPLE: ECONOMIC IMPLICATIONS OF BLEACHING



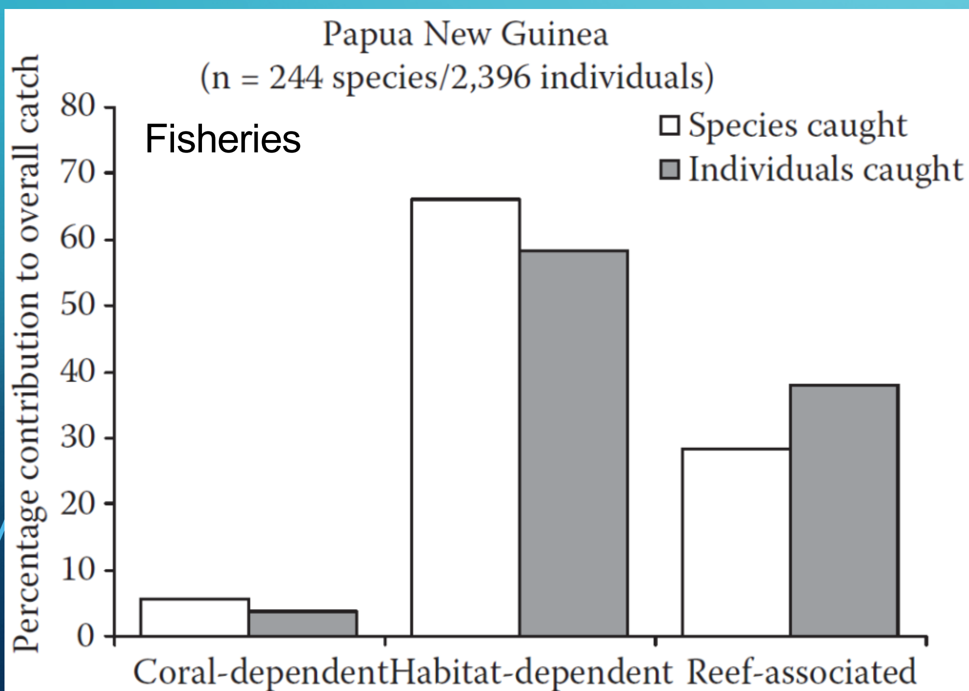


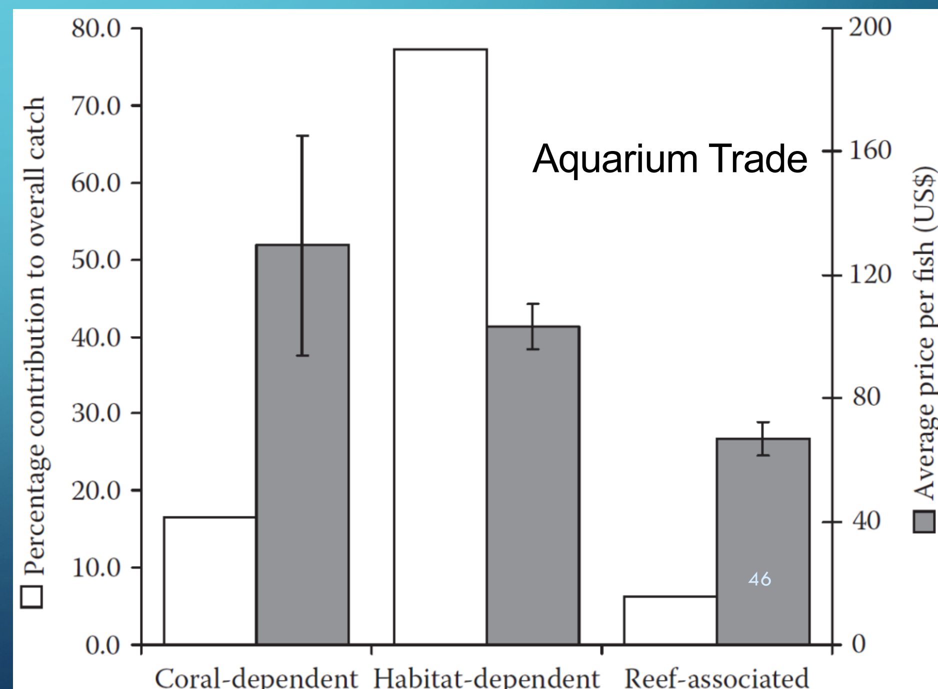
- Bleaching-induced mass mortality can cause loss of coral cover and complexity, and increased algae, that extends over a decade
- Coincides with dramatic shifts in fish communities, with certain groups particularly hard-hit

Pratchett et al 2008

EXAMPLE: ECONOMIC IMPLICATIONS OF BLEACHING

- Fishes important for local fisheries and international aquarium trade
  - Declines in amount & complexity of coral can markedly impact economic values
- Then add on impacts to tourism
  - Case Study: 1998 bleaching event in Indian Ocean (over 20 years) valued at US$ 8 bn
    - Fisheries: $1.4 bn; Tourism: $3.5 bn; Coastal protection: $2.2 bn; and Other services: $1.2 bn





HOW CAN INSURANCE MITIGATE & INCENTIVIZE?

INSURANCE AS A CONTRIBUTORY TOOL FOR REEF CONSERVATION AND RESTORATION

- Insurance capital lays the foundation for developing wider range of mechanisms to safeguard reef systems
- Success requires objective measures that correlate sufficiently with damage and restoration
  - Find a parameter (e.g., over-ocean wind speed, temperature) that can be *measured, monitored, reported (without much disagreement), and tracks (sufficiently) damage*
  - Examples
    - Relevant temperatures >2 C above mean summer maxima for 4 weeks
    - Windspeed over GPS-defined ocean area > 150 knots for target duration

REEFS REDUCE ENERGY FROM STORM SURGE…

BUT HURRICANES IN TURN DAMAGE REEFS…

REDUCING PROTECTION FOR THE FUTURE…

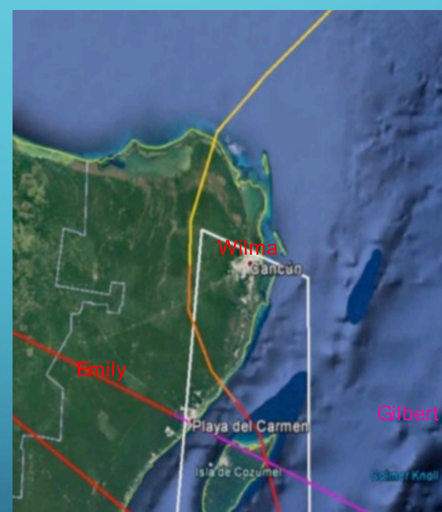
Research: Ismael Mariño Tapia, PhD, y Cesar Acevedo, MSc., 20
Photo Credit: Howard Lasker, University of Buffalo

SO IF A HURRICANE STRIKES CRITICAL REEF ASSETS…

WE CAN OBSERVE SPEED AND INTENSITY…

AND PAY IN DAYS TO PROTECT AND RESTORE…


Photo Credit: DGS UNAM Christian Volstrar



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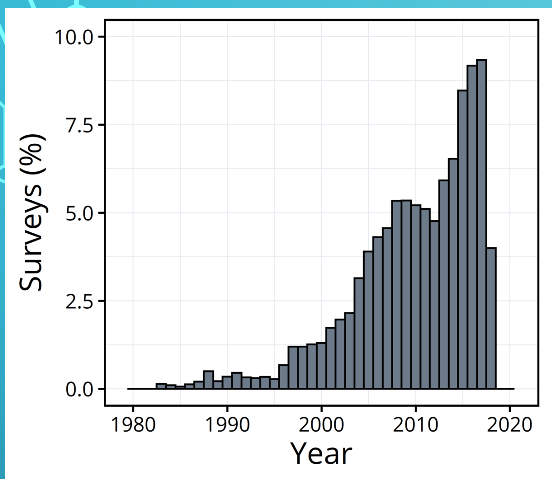
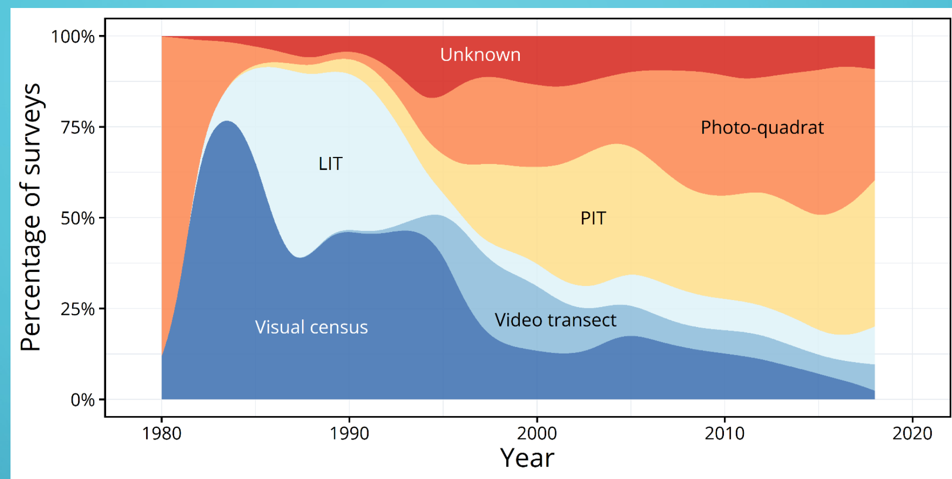
PARAMETRIC INSURANCE POLICY TO COVER MEXICO CORAL REEF – CLOSED IN EARLY JULY 2019

- Purchaser: Government of the state of Quintana Roo
- Cover: up to USD 3.8m to repair hurricane damage to reef
- Parametric product provided by Mexico-based insurer Afirme Seguros Grupo Financiero SA de CV
- Reefs sustain Quintana Roo’s tourism by providing coastal protection against storms, including reducing beach erosion
- Extreme storms put reefs at risk; between 20% to 60% of live coral cover lost after Category 4 to 5 hurricane compared with annual decrease of 2% to 6% in live coral due to other causes
- A Coastal Zone Mgmt Trust was built to finance insurance and promote conservation of coastal areas in the Mexican Caribbean. Trust will direct conservation investments for maintenance and repair of reefs and beaches; manage insurance payout, ensure conservation goals are achieved

- Partners: Nature Conservancy, State government of Quintana Roo, Cancún and Puerto Morelos Hotel Owners’ Association, CONANP, Mexican Universities, Afirme Seguros, Swiss Re Public Sector Solutions
- Trigger:
    - Wind speeds above 100 knots registered within covered area, triggers payout split of 50% for reefs and 50% for beaches
    - Payout increases up to annual aggregate limit over 12 month policy depending on wind speed:
        - 110 knots or more will trigger a payout of 40% of maximum limit
        - 130 knots will trigger an 80% payout
        - 160 knots will trigger full limit payout
- Note: Depending on storm severity, policy pays out up to limit. If limit not met on first storm, a second storm is still eligible for payout up to limit.

MONITORING DATA: IMPROVED QUANTITY & QUALITY





- Quantity of survey data available has grown exponentially since 1998 global bleaching event
- Transition away from visual to digital image bases approaches - amenable to machine learning analyses
  - Rapid growth in AI/ML for image post-processing
  - And non-diver-based surveying (ROVs and autonomous drones)

CORALNET
A WEB SOLUTION FOR CORAL REEF ANALYSIS

ReefCloud

Wicquart et al, in prep.; Souter et al. 2021

WHAT DID WE LEARN FROM MEXICO?

Successes

- Coverage put in place despite multiple stakeholders
- Parametric cover with measurable indicators shown to work without need for specialists
- Fund availability protected and payouts following disasters are timely (e.g., ear-marked payouts funded local brigades to clean coral from dirt after severe storms)
- Demonstrated that natural asset insurance is possible

Challenges

- Data collection can be difficult for model calibration (often missing baseline)
- Basis risk (gap between trigger & damage) may still be too large
- Global replication is difficult due to supply/ demand gap at current pricing, which means participation from NGOs and/or governments is likely necessary to expand
- Insurance industry still considers this type of cover experimental and not yet commercially viable

FINAL REMARKS

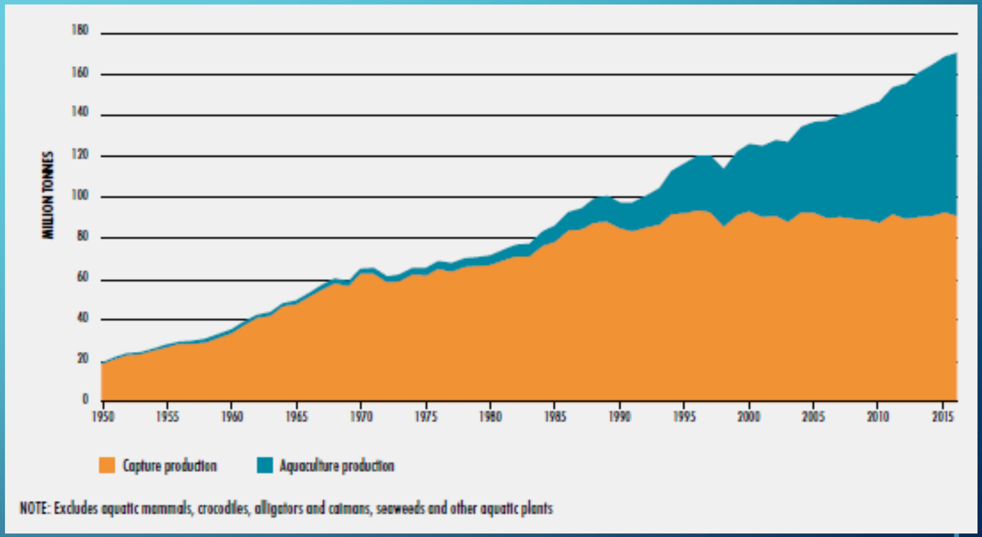
- Find better indicators/triggers for parametric insurance
- Educate stakeholders on how to implement effective cover
- Encourage more research and reporting related to reefs' economic value and mechanisms for protecting this value
- Archive baseline information, data, pictures, and video of existing reefs
- Develop better pricing & risk models related to reef insurance and relevant securities/derivatives
- *Collaborate across disciplines to find better models & solutions*

AQUACULTURE

WORLD FISH PRODUCTION

- World fish production in 2016: 171m tonnes
- Aquaculture share is 47% of total (53%, if non-food uses excluded)
- First sale FAO estimate USD 362bn, of which USD 232bn from aquaculture
- Between 1961 and 2016, average increase in global fish consumption was 3.2%, outpaced population growth (1.6%) and meat consumption (2.8%)
- China is the world's top producer (15.2m tonnes catches; 34m tonnes aquaculture)
- Northwest Pacific is most productive fishing area (22.4m tonnes catches, >25% of global catch)

World capture fisheries and aquaculture production

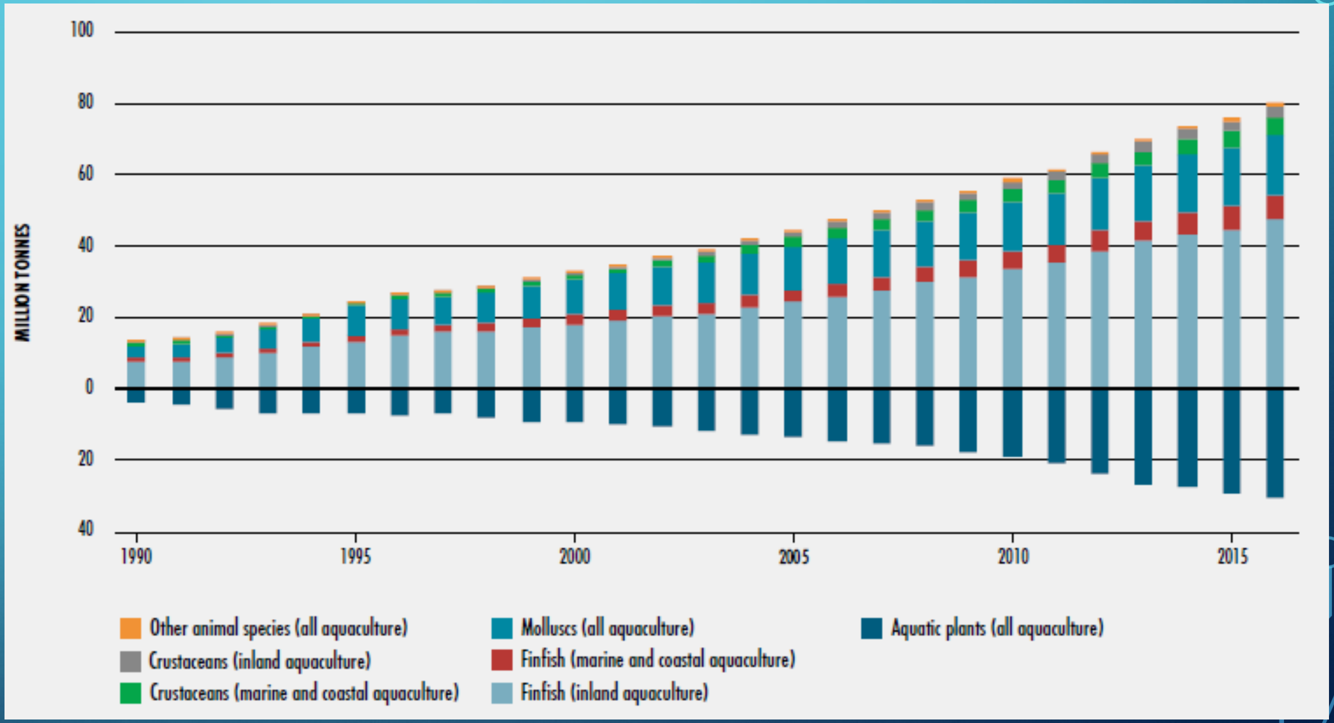


Source: FAO Fisheries – The State of World Fisheries and Aquaculture (2018)

TRENDS IN AQUACULTURE PRODUCTION OF FOOD FISH AND AQUATIC PLANTS1990-2016

2016 production: 80m t food fish (USD 231.6 bn) and 30.1 m t aquatic plants (USD 11.7bn)

- Finfish inland aquaculture 47.5m t
- Finfish marine/coastal aquac. 6.6m t
- Molluscs (all aquaculture) 17.1m t
- Crustaceans marine/coastal aquac. 4.8m t
- Crustaceans inland 3.1 m t
- Other animal species (all aquac.) 0.9m t
- Aquatic plants (all aquaculture) 30.1m t



Source; FAO Fisheries – The State of World Fisheries and Aquaculture (2018)

WORLD AQUACULTURE PRODUCTION OF AQUATIC PLANTS IS MOSTLY A SEAWEED MARKET

(THOUSAND TONNES. LIVE WEIGHT)

Species item	2005	2010	2011	2012	2013	2014	2015	2016
Eucheuma seaweeds nei, *Eucheuma* spp.	987	3 481	4 616	5 853	8 430	9 034	10 190	10 519
Japanese kelp, *Laminaria japonica*	4 371	5 147	5 257	5 682	5 942	7 699	8 027	8 219
Gracilaria seaweeds, *Gracilaria* spp.	933	1 691	2 171	2 763	3 460	3 751	3 881	4 150
Wakame, *Undaria pinnatifida*	2 440	1 537	1 755	2 139	2 079	2 359	2 297	2 070
Elkhorn sea moss, *Kappaphycus alvarezii*	1 285	1 888	1 957	1 963	1 726	1 711	1 754	1 527
Nori nei, *Porphyra* spp.	703	1 072	1 027	1 123	1 139	1 142	1 159	1 353
Seaweeds nei, Algae	1 844	3 126	2 889	2 815	2 864	449	775	1 049
Laver (nori), *Porphyra tenera*	584	564	609	691	722	674	686	710
Spiny eucheuma, *Eucheuma denticulatum*	172	259	266	288	233	241	274	214
Fusiform sargassum, *Sargassum fusiforme*	86	78	111	112	152	175	189	190
Spirulina nei, *Spirulina* spp.	48	97	73	80	82	86	89	89
Brown seaweeds, Phaeophyceae	30	23	28	17	16	19	30	34
Others	20	28	27	28	18	15	14	17
Total	**13 503**	**18 992**	**20 785**	**23 555**	**26 863**	**27 356**	**29 365**	**30 139**

Source: FAO Fisheries – The State of World Fisheries and Aquaculture (2018)

WORLD AQUATIC PLANTS MARKET IS DOMINATED BY CHINA AND INDONESIA

(THOUSAND TONNES. LIVE WEIGHT)

Country	2005	2010	2011	2012	2013	2014	2015	2016	% of total, 2016
China	9 446	10 995	11 477	12 752	13 479	13 241	13 835	14 387	47.9
Indonesia	911	3 915	5 170	6 515	9 299	10 077	11 269	11 631	38.7
Philippines	1 339	1 801	1 841	1 751	1 558	1 550	1 566	1 405	4.7
Republic of Korea	621	902	992	1 022	1 131	1 087	1 197	1 351	4.5
Democratic People's Republic of Korea	444	444	444	444	444	489	489	489	1.6
Japan	508	433	350	441	418	374	400	391	1.3
Malaysia	40	208	240	332	269	245	261	206	0.7
Tanzania	77	132	137	157	117	140	179	119	0.4
Madagascar	1	4	2	1	4	7	15	17	0.1
Chile	16	12	15	4	13	13	12	15	0
Solomon Islands	3	7	7	7	12	12	12	11	0
Viet Nam	15	18	14	19	14	14	12	10	0
Papua New Guinea	0	0	0	1	3	3	4	4	0
Kiribati	5	5	4	8	2	4	4	4	0
India	1	4	5	5	5	3	3	3	0
Others	25	14	15	16	13	12	16	8	0
Total	**13 450**	**18 895**	**20 712**	**23 475**	**26 780**	**27 270**	**29 275**	**30 050**	

Source: FAO Fisheries – The State of World Fisheries and Aquaculture (2018)

CHINA'S ROLE IN AQUACULTURE

- China has only gradually weakened its share in global production from 65% in 1995 to less than 62% in 2016 (Asian total share is 89%)
- Of all fish, aquaculture share in China is 73.7% (country's ability to feed its population with domestically produced fish)
- Sector is in deep transformation:
  - greater attention to environmental responsibility
  - quality improvement and product diversification
  - improved efficiency; strengthened business integration along value chain
  - new zoning, leading to large-scale removal of fish pens and cages from lakes, rivers and reservoirs
  - introduction of new technologies: large-scale expansion of crop-fish integration (incl. rice-fish culture)

Source; FAO Fisheries – The State of World Fisheries and Aquaculture (2018)

AQUACULTURE RISKS

- Mechanical/electrical breakdown
- Algae bloom
- Natural perils
- Water temperature
- Salinity
- Water depth
- Feed
- Changes in water quality
- Water quality
- Diseases
- pH-value
- Medical treatment
- Current/tidal wave
- Pollution
- Jelly fish
- Predators/theft – malicious acts

Source: Swiss Re, Agriculture Reinsurance

TRENDS IN AQUACULTURE INDUSTRY

- Complex, vulnerable farming systems
- Many factors influence exposure:
  - farm management experience
  - animal traits (needs, stress factors)
  - location (off-shore, tide, waves)
  - breeding conditions (water quality, pH, temperature)
  - environment (neighbourhood, harbour, shipping routes)
  - equipment (mooring, back-up)
  - natural hazards (storm, algae bloom)
- Increased reputational risk (tuna, salmon)

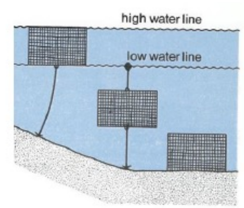
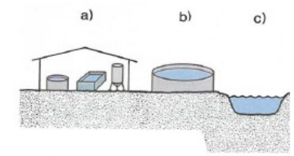
- Frequency and intensity of natural catastrophes expected to rise beyond normal cyclical fluctuations
- Production cost on the rise
- Constant pressure to increase productivity
- Battle for promising markets and farms
- Increasing values, concentration:
  - “old” type of cage: 600m3
  - “new” type of cage: 60’000m3
  - insured value: up to USD 2.5m per cage
- Farming new species
- Multi-trophic farms

Source: Swiss Re, team Agriculture Reinsurance

AQUACULTURE INSURANCE

- young, developing market
- know-how, risk assessment, and on-site visits are key
- hardly any premium subsidies
- volatile results; 20y average loss ratio 60-70%

Husbandry systems

	Off-shore	On-shore
		
Structure	• cages • open seawater	• ponds • tanks • artificial water systems
Main Perils	• storm • algae bloom / jelly fish • diseases	• pollution • machinery breakdown • diseases
Species	• salmonides • sea bream, sea bass • other	• carps • salmonides • flatfish • other

Source: Swiss Re, team Agriculture Reinsurance

AQUACULTURE INSURANCE CHALLENGES

Two key parameters in natural catastrophe (nat cat) insurance

- basic annual loss burden
- extreme event losses

Key parameters differ from peril to peril and require different analytical approaches

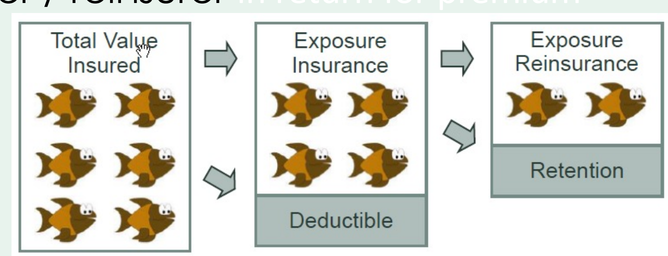
- accurate estimate of occurrence frequency
- reliable estimate of possible loss size
- need to consider location specific factors

Aquaculture insurance coverage

- mortality of fish stock losses
- property/equipment damage
- transport

Risk transfer

Insurance = contractual risk transfer assumed by insurer / reinsurer in return for premium payment



Source: Swiss Re, Agriculture Reinsurance

AQUACULTURE INSURANCE PRODUCTS (1/2)

	Stock mortality	Equipment	Transport
Cover		all risks" or mortality / loss of stock due to specific perils	
Sum insured	Agreed values based on monthly production plans and basis of indemnity per unit	Replacement costs by using depreciation factors	Agreed values
Limit	Fixed amount according to max projections, allowing for an additional 10-20% margin	Fixes amount as per sum insured	
Deductible	▪ Agreed % of the value of risk at the time of loss (per group of cages, per location, per total value at risk); ▪ Range between 10-30% ▪ Co-insur. approp. to lower premium burden of the assured; ▪ Each and every loss		
Indemnity	▪ Lost fraction of the value of risk at the time of loss; ▪ Professional and experienced loss adjusting of utmost importance		
Rating	▪ Premium calculated on basis of individ. risk (%of sum insured) ▪ Range: 1.5-5% and higher (depends on type of risk, deductible, species, location) ▪ 80% of projected premium to be paid to insurer		

Source: Swiss Re, Agriculture Reinsurance

AQUACULTURE INSURANCE PRODUCTS (2/2)

	Stock mortality	Equipment	Transport
Common exclusions	▪ Governmental slaughter order / intentional slaughter of stock ▪ Mysterious and unexplained shortages of stock ▪ Malicious or wilful acts of the insured or employees ▪ Radioactive contamination ▪ Sonic band, war, civil war, nuclear, terrorism, sanctions, …		
Obligations of the insured	▪ Immediate notification of the insurer in case of loss ▪ Sound and proven fish farm mgmt. methods ▪ Regular stock control ▪ Preparation of monthly stock declarations to the insurer ▪ Loss prevention		
Warranties	▪ Compliance with stocking density limits during production ▪ Sound health of stock at inception of insurance ▪ No material changes to systems and devices ▪ Maintenance of all equipment and stock in good order		
Clauses	▪ Loss occurrence definition ▪ Time limit clause		

Source: Swiss Re, team Agriculture Reinsurance

INSURABILITY REQUIREMENTS AND CONCLUSIONS

Requirements for aquaculture insurability

- Original risk
  - suitable location and environment
  - appropriate technology/equipment/installations
  - skilled and experienced farm mgmt. and professional workers
  - stock quality
  - medical / veterinary support
  - transparent mgmt. procedures (espec. mitigation strategies in critical situations)
  - economic situation (-> farm records, cost structure, …)
- Primary insurer
  - claims handling process (eg independent loss adjuster)
- Regulatory environment
  - clear and transparent local regulatory rules

Conclusions

- Aquaculture is a growing but volatile industry => re/insurance as an important component in risk mitigation
- Aquaculture remains reinsurable – but reinsurance must make economic sense
  - risk selection and geographical diversification as key elements
  - focus on bottom line and maintain UW discipline
  - need for more accurate and detailed data
- Impact of climate change hard to quantify but relevant for specific locations
- Reputational issues for aquaculture industry become more important
- Changed insurance role: from retailer to relationship/know-how provider (perils, risk assessment, loss adjustment)

Source: Swiss Re, team Agriculture Reinsurance

OCEAN RISKS AND ECOSYSTEM SERVICES

Natural hazard risk	Ecosystem service
Environmental pollution (anthropogenic)	Ecosystem service
Human-centered emissions	Water dilutes gases, fluids and solid waste from human activities
Agricultural pollution	Bio-remediation or filtering (living organisms degrade, reduce, and/or detoxify contaminants over time)
Climate-change-driven hurricanes/typhoons	Global and regional climate regulation through the long-term storage of carbon dioxide
Ocean acidification	Production of fibres and other materials from plants, algae and animals
Unusual levels of precipitation	Maintenance of hydrological cycle

Source: UNEP Encore database

FORESTRY

FOREST CLASSIFICATION

Category	Type of forest	Forest area worldwide (million ha)		
		1990	2015	Change
Natural forest	Primary forest: forest of native species in which there is no human activity and ecological processes are undisturbed – mostly in governmental/public ownership Modified natural forests: forests of naturally regenerated native species in which there are clearly visible indications of human activity – mostly in governmental/public ownership	3949 (96%)	3710 (93%)	−239 (−6%)
Planted forest	Semi-natural forest: forests comprising native species, established through planting, seeding or assisted natural regeneration Productive forest plantations: primarily established for timber and fibre production Protective forest plantations: primarily established for conservation of soil and water	179 (4%)	289 (7%)	+110 (+61%)
Total forest area		4128 (31.6%)*	3999 (30.6%)*	−129 (−3%)

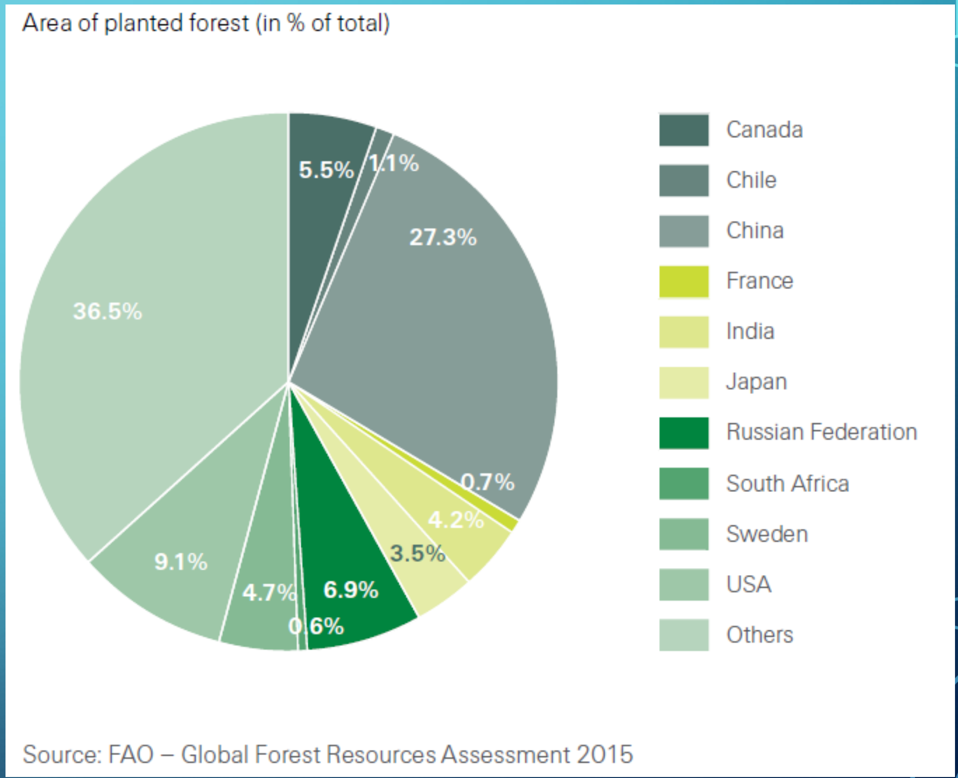
*Percentage of global land area

Source: FAO – Global Forest Resources Assessment 2015

TIMBER PRODUCING COUNTRIES

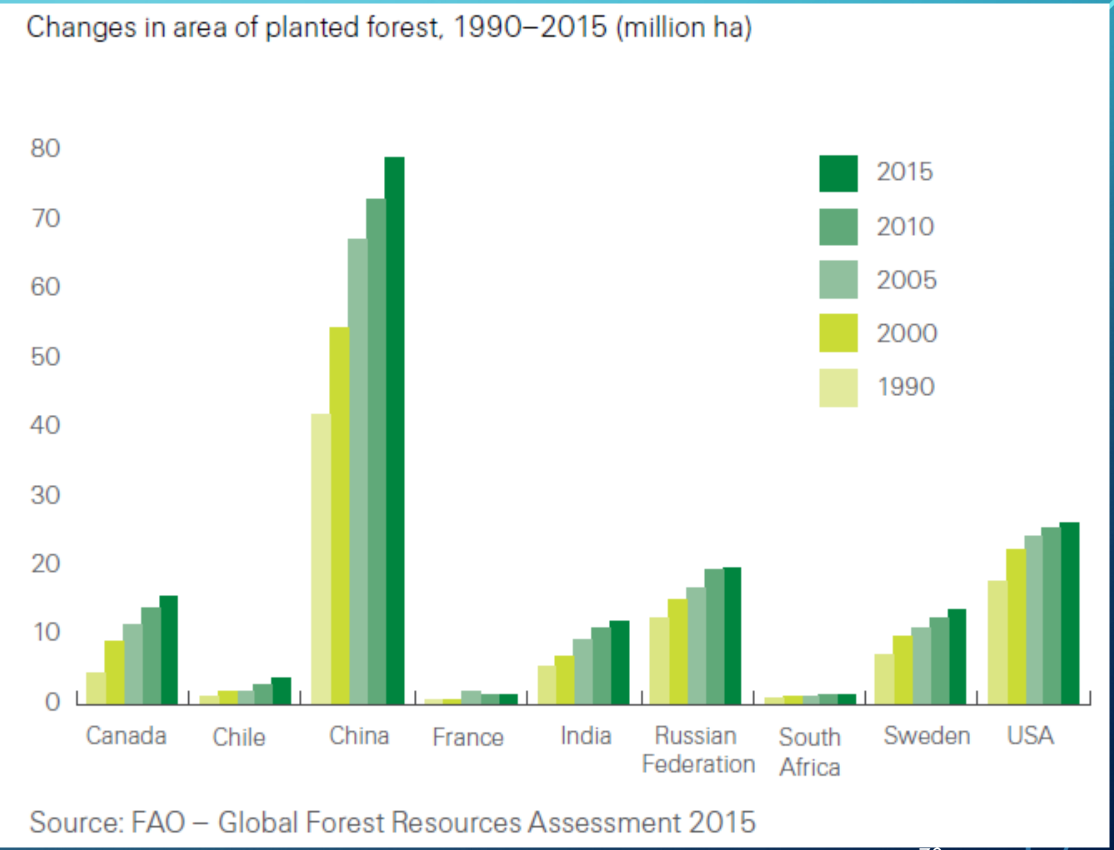
- planted forests rely on intensive land use and focus on a small number of species, creating high concentration of values and hence a heightened risk exposure

=> quest for forestry insurance



TRENDS IN FOREST PLANTATIONS

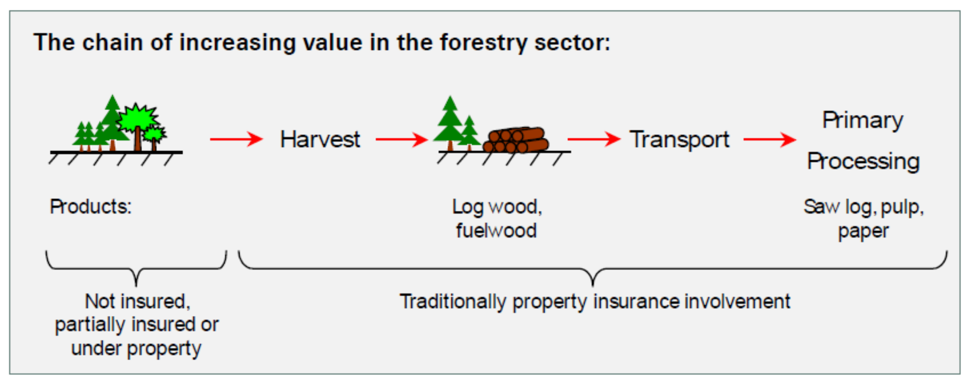
- Largest and strongest growth in China
- Most common tree cultivations are eucalyptus, pine trees, acacia, bamboo
- Forest plantations are mostly managed professionally
- Forest plantations bear high risk of monocultures => vulnerable to insects and diseases; higher storm risk
- Further increase in area expected, driven by international demand for forest as a carbon sink (climate change), demand for timber (ie housing), renewable energy



Source: Swiss Re, Managing forestry risks, Swiss Re 2015, and Swiss Re Institute

FORESTRY MARKET TRENDS

- 2/3 of insured forests are insured under property policies
- 1/3 of insured forests are insured under forest policies
- Premium volume is around >150m USD
- Insurance penetration around 10% of all plantations



Source: Swiss Re, Agriculture Reinsurance

SUSTAINABILITY

- Re/insurers covering forestry may run the risk of unintentionally supporting illegal logging activities or adverse environmental or social impacts
- Swiss Re has a sustainability risk framework to identify and address the risk in re/insurance and investment transactions that arise from sustainability challenges
- Framework has eight policies, incl. forestry & logging
- Swiss Re will not provide insurance for activities that
    - violate local, national, international law or binding agreements regarding illegal logging, incl. the illegal use of fire
    - adversely affect world heritage sites or ecological sensitive areas
    - involve involuntary resettlement, impact vulnerable social groups or indigenous peoples and restrict access of local populations to natural resources
    - are conducted in weak regulatory environments w/o sustainability certification

Source: Swiss Re Sustainability Risk Framework

MANAGING FORESTRY RISKS

Risk category	Risks
Biological growth	**Natural hazards**
	Pests, diseases, fungi, animals, insects
Markets	Timber prices
	Input costs
	Land value
Country	Regulatory framework
	Political/legal framework
	Tax regime
	Currency

Forestry insurance covers:

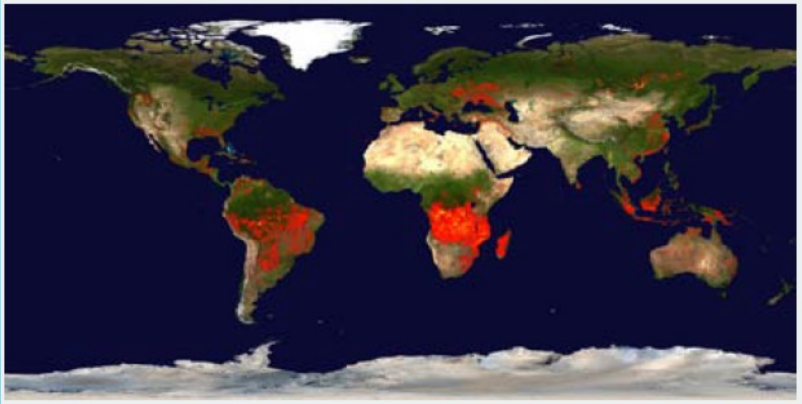
- FLEXA, Windstorm
- Ice/Snow, Flood
- Hail, Earthquake

Fire and windstorm are the two most important insurable risks for planted forests.

Source: Swiss Re

FOREST FIRE RISK MODELLING

Fire risk models are becoming increasingly important to understand fire risks and improve fire disaster prevention and mitigation measures. Swiss Re has developed a fire model based on so-called forest fire weather indices to predict the risk of forest fires worldwide. The underlying concept is to link different weather parameters, eg temperature and wind speed, with fire characteristics, such as burnt area and frequency. Using insights into the relationship between weather and fire derived from long weather time series, the expected forest fire risk is estimated for different forest regions or plantations.



This fire map accumulates the locations of the fires detected by MODIS on board the Terra and Aqua satellites over a 10-day period from 19-28 August 2015. Each coloured dot indicates a location where MODIS detected at least one fire during the compositing period. Colour ranges from red, where the fire count is low, to yellow, where number of fires is large. We acknowledge the use of data products or imagery from the Land, Atmosphere Near real-time Capability for EOS (LANCE) system operated by the NASA/GSFC/Earth Science Data and Information System (ESDIS) with funding provided by NASA/HQ. For more detailed information go to: https://earthdata.nasa.gov/earth-observation-data/near-real-time/citation

Source: http://lance-modis.eosdis.nasa.gov/cgi-bin/imagery/firemaps.cgi (NASA)

VALUATION APPROACHES

- **Cost approach:** Total cost incurred to date, ie the costs for establishing and maintaining a forest. This valuation method is normally used only for very young forest stands.
- **Realization value**: The value that would be realized if the timber were harvested. This method can be used only once the forest is marketable, ie after it has been thinned for the first time. The main calculation factors are the standing timber volume and the current market price.
- **Net present value (NPV) or net discounted revenue (NDR) valuation**: This method is based on projected future incomes and costs discounted to the present day at a specific discount rate (discounted cash flow, DCF).
- In some cases, none of these valuation methods are applied. Instead, the agreement is reached that the forest owner receives a fixed amount per m3 of timber in compensation if a loss occurs. This has the advantage of facilitating swift payment following a loss event. The downside is that it is a uniform process and as such may not be feasible for heterogeneous forest stands.
- **Rule of thumb:** The insured value of standing timber largely depends on the tree species, age, yield class and soil type, and usually lies in the range of USD 1 000 to 3 000 per hectare. If the value is above USD 3 000 per hectare, the reasons for such high values should be assessed carefully.

Source: Swiss Re, Managing forestry risks, Swiss Re 2015

UNDERWRITING CONSIDERATIONS

- Sound and sustainable forest management practices, including a certificate label, eg FSC, PEFC
- Appropriate technology, equipment and installations available
- Skilled and experienced management and professional workers
- Transparent risk management procedures, particularly mitigation strategies in critical situations
- Clear management responsibilities and land title
- Comprehensive and solid financials with a sustainable investment case
- Minimum diversification of asset base
- Adequate and comprehensive valuation methodologies for timber (eg reasonable timber price market assumption)
- Basic information, such as tree species, yield classes, age class distribution, standing timber volumes, annual growth rates, rotation periods and silvicultural measurements
- Loss and exposure history

Source: Swiss Re, Managing forestry risks, Swiss Re 2015

FORESTRY INSURANCE PRODUCTS (1/2)

Peril	Information
Fire	▪ Catastrophe potential; dominant cause of loss for insurers ▪ Influence of “natural” and socio-economic factors (vast majority of all wildfires start in the context of land use ▪ Loss costs for commercial plantations (in % of total area exposed): 0.2-0.6% ▪ Insured values for standing timber: re-establishment costs, value of stumpage, compound costs of investment, net present value of future cash flows; typical values are 700-10’000 USD/ha ▪ Insured values for other covers: fire fighting costs ▪ Fire loss limit: for large plantations >50m USD
Wind	▪ Catastrophe potential ▪ Often not insured due to insurers’ accumulation issues with other property storm coverage ▪ Mid to high latitude countries are more exposed ▪ Risk of wind damage very strongly influenced by mgmt. factors, topography, location, tree age and harvesting system ▪ Immediate impacts often smaller than indirect impacts (fires, insect outbreaks, disease) ▪ Difficult as-if considerations from past event to future due to changed forest area (growth, age classes, species, standing timber volume, …), climate change, lack of reliable and representative loss data

Source: Swiss Re, team Agriculture Reinsurance

FORESTRY INSURANCE PRODUCTS (2/2)

Peril	Information
Hail	▪ May cause big losses in nurseries and during the period immediately after planting out in the plantation ▪ Effect usually one of temporarily impaired growth
Snow	▪ Weight of snow has produced few claims in the past ▪ Attritional loss in high latitude forests ▪ Weight of snow combined with storm can produce severe claims
Ice	▪ More devastating than snow weight ▪ Rare, but may be widespread (eg Eastern Canada provinces 1999)
Flood	▪ Flood risk is a function of location (flood plains) and susceptibility to immersion by water ▪ Cover is possible if the timber is not in an area which floods regularly

Source: Swiss Re, team Agriculture Reinsurance

CHALLENGES TO FORESTRY INSURANCE

- Correct premium calculation (vulnerability: correlation between storm model and the effective loss)
- Awareness & willingness of forest owners to insure and pay the premium
- Low frequency, high severity (long period w/o losses)
- Geographical diversification (sizeable portfolio)
- Development of timber prices
- Loss assessment after catastrophic events
- Availability of governmental subsidies
- National catastrophic fund

- Low insurance penetration
  - needs increased risk awareness of forest owners
  - clear and understandable insurance product based on the needs of the forest owner
  - affordable premium rate
  - potential involvement of state
  - voluntary vs mandatory scheme
  - forest land consolidation

Source: Swiss Re, team Agriculture Reinsurance

INSURABILITY REQUIREMENTS AND CONCLUSIONS

Requirements for forestry insurability

- Original risk
  - appropriate technology/equipment/installations
  - skilled and experienced forest mgmt. and professional workers
  - transparent mgmt. procedures (espec. mitigation strategies in critical situations)
  - economic situation (-> forestry records, cost structure, …)
- Primary insurer
  - claims handling process (eg independent loss adjuster)
- Regulatory environment
  - clear and transparent local regulatory rules

Conclusions

- Increased demand for wood/pulp/paper covered more by wood from forest plantations, leading to
  - intensification
  - rationalization
  - concentration on a few species
  - concentration of value on a relative small area
- Plantations as highly specialized line of business (risk mgmt. very important)
- Expanding field of stakeholders (with interests in very different camps)
- Previously unmarketable forest goods are now being evaluated and thus becoming tradable -> forest gain in value
- => increase in demand for re/insurance

Source: Swiss Re, team Agriculture Reinsurance

ADD-ON: (PERI-) URBAN FORESTS RISKS AND ECOSYSTEM SERVICES

Natural hazard risk	Ecosystem service
Strong wind (typhoon, hurricane)	Act as barriers, reduce wind speed, work as protection screens
Flooding, drought	Reduce stormwater volumes and flood risk, increase precipitation interception. Increase water infiltration and groundwater recharge
Landslides	Increase stability of steep slopes by reducing surface run-off and erosion
Soil loss	Prevent soil erosion. Reduce impact of raindrops, improve soil-water retention
Extreme heat/cold, urban heat island effects	Cool by shading, evapotranspiration, etc.;: protect from hot and cold winds
wildfires	Reduce the fire intensity, flammability and spread when properly designed and managed
Biodiversity loss	Conserve species/habitat, limit spread of invasive species
Pests and diseases	Limit spread and impacts
Environmental pollution (anthropogenic)	Ecosystem service
Air pollution	Sequester carbon, reduce ozone formation, capture particulate matter and gaseous pollutants, reduce emissions of allergens
Pests, diseases	Provide buffer against invasive species
Reduced physical or mental health	Provide pleasant spaces that increase well-being, social cohesion and interaction, and leisure activities, etc.

Source: Carinanos et al 2018

RESILIENCE BONDS

"CLIMATE BONDS" (E.G., CLIMATE BOND INITIATIVE)

- Target financing of projects shifting to a low-carbon-emission environment, mitigating climate change, and/or building resilience to climate-driven catastrophic risk.
- Certify and monitor compliance with specified focused, narrow, measurable, and monitorable climate standards.
- Develop and educate a community of auditors, reporters, and evaluators
- Separate credit assessment from climate-standards assessment
- Important to link attestation and evaluation to objective (or as objective as possible) and easily measured indicators
- Relevant bond types:

1. Use of proceeds: Recourse-to-the-issuer debt obligation attested by internal process linked to operations
2. Use of revenue processed: Non-recourse debt obligation pledged against specified cash flows attested by internal process
3. Project bond: Can be non-recourse or not
4. Securitized bond: Collateralized by one or more eligible and attested projects

"RESILIENCE BONDS"

- Similar design to climate bonds
- Add step-up or step-down coupons as a function of achieving target outcomes
- Develop more creative re-payment possibilities e.g., government grants or awards following successful deployment of proceeds meeting measurable outcomes.
- Implement covered bonds with dual recourse (both to underlying project portfolio cash flows and banks underwriting debt)
- Governments can support with the following:
  - Initial funds to explore opportunities
  - Facilitate creation of "information utilities" to ensure measurable indicators are implemented and maintained
  - Back-stops to limit extreme tail risk
  - Price subsidies to close demand/supply gap
  - Provide tax breaks to investors in these bonds

RESILIENCE BOND STRUCTURE PARTICIPANTS

Target project: Mitigate Wildfire

Sponsor
- Technical work
- Structure

Issuer
- Manage issue
- Ensure compliance

Investor
- Buy issue
- Evaluate & monitor
- Validate

Public partner
- Seed funding
- Subsidies
- Grants

DISCUSSION

EMERGENCE OF ESG AND RESILIENCE: LESS-WELL-DEFINED, BUT MATERIAL RISKS

- Environment: Carbon emissions, pollution
- Social: Labor practices, gender/race distributions
- Governance: Board independence
- Resilience: Catastrophic events preparedness, dependent lifeline network robustness, cyber-attack preparedness

TRENDS FACILITATING GREEN-FINANCING INSTRUMENTS: QUANTIFY, ANALYZE, REPORT, AND MONITOR

- Data more important than models
- Well-curated data are most important (60% of time spent on cleaning & curation)– new tools becoming available
- More data and more alternative data (particularly meta-data) are available
- Increasing availability of guidelines (e.g., Climate Bond Initiative)
- Increasing availability of hardware for…
  - Sensors
  - Authentication (e.g., distributed ledgers)
  - Networking (e.g., IIoT)
  - Compute
  - Visualization
  - Decision support
- Increasing discussion, study, and experimentation with **parametric** instruments

SUSTAINABILITY REQUIRE RESILIENCE MODELS FOCUSED ON LLN AND ESS

- System of systems in urban areas create potentially more fragile environments
- Man-made catastrophic risk arising from cyber attacks, terrorism, wars, and telecommunication disruption should be assessed
- Earthquakes, volcanoes, and severe convection storms can be more devastating in the light of urbanization and globalization
- *A networked infrastructure perspective using **"digital twins"**, sensors, and the industrial internet of things (IIoT) is foundational for designing new green/sustainability-focused financial instruments*
- ***Dependency risk**-– especially related to lifeline networks such as power, transportation, telecommunications, and supply chains– has become an important focus.*
- ***Parametric insurance** and **green/resilience/climate bonds** can facilitate better resource allocation*

REFERENCES

- van Toor, J., Piljic, D., Schellekens, G., van Oorschot, M., Kok, M., June 2020, “Exploring biodiversity risks for the Dutch financial sector,” Dutch National Bank.