מרכז הידע והמחקר הלאומי בתחום ההיערכות למצבי חירום
National Knowledge and Research Center for Emergency Readiness

Insurance, Thresholds and Mechanisms for Post Disaster Resilience

Final report for the National Knowledge and Research Centre for Emergency Readiness

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I. Background and goals

- Climate-related disasters are growing worldwide and are expected to worsen with climate change.
- Extreme events disproportionately affect food security and the livelihood of the poor, over 75% of whom earn their living from agriculture (Conforti, et al, 2018).
- According to future projections published in an IPCC report (Masson-Delmotte, et al, 2018), farmers in many parts of the world will face more challenging conditions characterized by a warmer environment, more erratic rainfall patterns, and more frequent extreme events.
- 23% of all damage caused by disasters triggered by natural hazards such as droughts, floods, or tsunamis is registered in the agricultural sector, totalling about 96$ billion damage to crops and animals over the 10-year period of 2005–2014 (Conforti, et al, 2018). Consequently, countries whose economies depend on agriculture are the most affected by disasters triggered by natural hazards (Barnett & Mahul, 2007; Loayza, et al, 2012).
- One of the ways of reducing the economic damage of catastrophic events on the agricultural sector is to provide insurance that eases the financial impact on those directly affected (Hazell et al., 2010; Krieger & Demeritt, 2015; Kunreuther, 2015; OECD/The World Bank, 2019; Swain, 2014).
- In principle, traditional insurance instruments, including those at the agricultural sector like crop insurance, can be used to transfer the market risk of extreme weather events from a risk-averse individual to a risk-neutral insurer (Porrini & Schwarze, 2014) by enabling the market to carry a portion of the cost and adapting to climate change events (Partridge & Wagner, 2016).
- The thresholds of insurance contracts in the agricultural sector often insure against weather events, including exposure to cooling degree days, heating degree days, growing degree days, or crop heat units (Turvey, 2001). Thresholds can be measured by either a single or multiple event, while the payout can be either fixed or dynamic according to the type of damage or event (Dessai et al., 2003; Lewis & Murdock, 1996; Pagano, et al, 2018).

- There is, a lack of rigorous studies depicting the range of thresholds for extreme events in the agricultural sector, and there is no conceptual framework for understanding how a threshold is selected in real-life situations. It has been suggested that this lack of clarity creates uncertainty for those affected by disaster events (Sandink, et al, 2016) and affects the ability of farmers to purchase insurance (Leblois & Quirion, 2013) or make a fully informed choice (Patt et al., 2010).
- In order to address this gap, the current study established an archetype of insurance thresholds regarding the agricultural sector's vulnerability to extreme events which was validated by a real-life case study for understanding the pattern of variance over time.

II. Abstract

The use of insurance against disasters triggered by natural hazards has become a common mechanism in the agricultural sector. Typical insurance policies, including those in the agricultural sector, specify an event or threshold beyond which insured payments are triggered. However, there is an absence of studies situating agricultural insurance against natural disasters in the wider insurance framework or depicting the range and evolution of thresholds for extreme events in the agricultural sector. As a result, there is no conceptual framework for understanding how a threshold is selected in real life situations. This study comes to address this gap by developing an archetype for threshold selection under conditions of climate mitigation and adaption uncertainty, and by verifying the archetype through an Israeli insurance case study. The study first unpacks the concept of insurance thresholds and identifies its evolution along time as well as its main building blocks: insurance realm, primary thresholds, and risk indicators. It then assembles these building blocks into three generic trajectories (climate exposure, location exposure, and sensitivity), each driven by different external and internal variables. Next, the architype was applied to the Israeli Nature Damage Fund – Kanat in order to trace how the choice of thresholds changes along time by measuring the number of thresholds for 30 sub crops in their agriculture insurance contract along a period of 10 years and by detecting changes in time in threshold. Finally, the study lays the foundation for treating the topic of insurance threshold as a research agenda

III. Detailed report

The Sectorial context of disaster Insurance

- Agriculture, urbanism, and tourism are the three main sectors that are exposed to natural disasters and thus often covered by insurance against natural disasters.

- The difference between these sectors, lies in their vulnerability to natural disaster, namely, the ability of individuals, communities, and institutions to mitigate and/or recover from natural hazards and the ensuing responses (Baker, 2009).
- The agricultural sector is more sensitive to temperature variability, droughts, and frosts, which may cause fires and diseases and affect crops and livestock.
- Agricultural production is highly exposed to climate extremes due to a lack of infrastructure, irrigation, flood protection, or drought resistant crops (Weingärtner et al., 2017).
- The agricultural sector has four main insurance types: 1. crop insurance which covers damages for yield reduction in open land and crop revenue due to disasters (Diaz-Caneja, et al, 2008; Glauber, 2016; Rural, 2001); 2. forest insurance which is characterized by small forest owners and vulnerable tree species and therefore covers damages for the loss of tree crops and carbon units[1] (Brunette et al., 2015; Subak, 2003); 3. livestock insurance which covers damages for the death of livestock and decline in the price of animals due to disaster (Chantarat et al., 2013; Collins, 2011; Ye et al., 2017); 4. aquaculture insurance which covers damages for aquaculture loss of production, loss of life, infrastructure damage such as to boats, electrical systems, pumps, and gates, and deteriorating water quality (Beach & Viator, 2008; Xinhua et al., 2017; Zheng et al., 2018).

Table 1 sums up the differences in insurance types and vulnerabilities between the three main sectors.

[1] In order to reduce carbon, any lost carbon is replaced by purchasing replacement credits. A concern with this type of arrangement is that the project developer or other responsible party may not have the resources to replace the lost carbon. The risk of defaulting on project commitments is greater with large losses and the risk increases with the possibility that credit value and, therefore, replacement costs, will rise over time.

Table 1: Insurance types and vulnerabilities of the different sectors to natural disaster

Sector	Source of vulnerability	Insurance mechanism	Insurance type	Damage covered	References
Agriculture	➢ Lack of infrastructures or irrigation. ➢ Lack of flood protection or drought resistant crops. ➢ Economic dependence. ➢ Geographical dispersion. ➢ Depends on biological processes	Public-Private partnerships (PPP)	Crop insurance	➢ Yield reduction. ➢ Crop revenues	Nnadi et al., 2013; Noy et al., 2017; Raschky & Chantarat, 2020; Weingärtner et al., 2017; Zulfiqar et al., 2016
			Forest insurance	➢ Loss of tree crops. ➢ Loss of carbon units	Brunette et al., 2015; Dai et al., 2015; Holecy, & Hanewinkel, 2006; Subak, 2003
			Livestock insurance	➢ Livestock death ➢ Decline in price of animals	Chantarat et al., 2013; Collins, 2011; Ye et al., 2017
			Aquaculture insurance	➢ loss of aquaculture production ➢ loss of life ➢ Infrastructure ➢ Water quality	Beach & Viator, 2008; Xinhua et al., 2017; Zheng et al., 2018
Urban	➢ Increase in population. ➢ Construction in risk areas. ➢ Rising construction cost	Private, government and PPP insurance contracts	Flood insurance	➢ Building and property coverage	Clarke & Grenham, 2013; Kousky & Michel-Kerjan, 2017; Landry & Jahan-Parvar, 2010; Oulahen, 2015
			Earthquake insurance		Athavale & Avila, 2011; Noy et al., 2017; Xu et al., 2018
Tourism	➢ Mobility. ➢ Small business. ➢ Uncertainty of attraction climate	Private contract	Tourism insurance	➢ Access prevention	Becken & Hughey, 2013
			Attractions insurance	➢ Booking cancelation ➢ Infrastructure	Fitchett et al., 2016; Olya & Altinay, 2016; Tsai, 2013

The evolution of agricultural insurances

- The rise in global temperature increases the need for adaptation to actual or expected changes in climate and its effects. Adaptation involves building capacity to respond better to climate change impacts such as providing different types of insurance (de Coninck, et al, 2018).

- Agricultural insurance against disasters triggered by natural hazards has evolved with time to include four main elements: **the insurance mechanism; the risk covered; the scope of coverage; and a threshold index.**
- **Insurance mechanism** is the institutional structure of financial risk management through relief compensation (Bielza, et al, 2007). It is based on the division of responsibilities between stakeholders, the funding and coverage conditions that vary according to the mechanism, and incentives for mitigation measures (Paudel, 2012). The mechanism may be a private insurance contract, a public system referring to a government contract, or a PPP. Most of the private or PPP mechanisms are based on insurance contracts, while the public system is mostly based on regulations (Bielza, et al, 2007).
- Insurance mechanisms differ not only in their structure but also in how they address **risk**. They are exposed to two types of risks: local and global. Contract insurances were initially designed to address local risks as yield insurance. Yield insurance insures the main risks affecting production in a certain (localized) area, such as insufficient rainfall, extreme temperatures, hail, insects, and diseases. As agriculture became affected by global processes, new types of risk emerged. Due to agricultural trade liberalization, agriculture is exposed not only to local production but also to the global prices of agricultural commodities. This fluctuation in prices prompted revenue insurance, which depends mostly on future market prices (Diaz-Caneja, et al, 2008).
- **Coverage** specifies which crops and areas are included in the insurance mechanism. Most of the early mechanisms provided coverage for a single or just a few crops or perils in a non-systemic way (most often hail or hail and fire), while others were not covered at all (Diaz-Caneja, et al, 2008). This type of single risk insurance was, however, criticized for not covering all extreme events, and many countries later decided to expand the insurance mechanism to cover a higher diversity of crops and greater perils (Enjolras, & Sentis, 2011).
- Another change in agricultural disaster insurance is around how compensation is measured and what threshold qualifies for compensation. This change is evident in the move from a **direct to an indirect index,** which is based on changes in the agrotechnology remote sensing that calculates the damage and the areas at risk. A direct index is homogenous compensation to a particular region based on the exposure of the entire region to a disaster. In such cases, if the area yield goes below a given value, all the insured farmers in that area receive uniform compensation regardless of their true losses. With contemporary advancements in remote sensing technology, it has become clear that the exposure to risk is not

homogenous and, similarly, that the damage is not distributed equally in space and between farmers. This ability to gauge the actual damage to individual farmers has shifted the coverage from a direct to an indirect index. An indirect index refers to indemnities that are calculated for the individual farmer and are often based on an index external to the farm, such as meteorological indicators or satellite pictures. Compensation is thus given according to the farmer's actual damage and not the exposure to risk (Shields, 2015).

Table 2 sums up the four main elements of insurances that address disasters triggered by natural hazards in the agricultural sector. It also highlights their evolution over time.

Table 2: The Evolution of Agricultural Disasters triggered by natural hazards Insurances

	Timeline →		
Mechanism	Private insurance contracts	Government contracts	Public-private partnership
Risk covered	Local (yield insurance)		Global (crop revenue)
Scope of coverage	Single risk/crop		Multiple risk/crop
Threshold index	Direct (1) Homogenous area (2) Exposure based		Indirect (1) Heterogeneous (2) Damage based

Disaster insurance thresholds

- In the insurance world, threshold concepts are a way of estimating the financial impact of a disaster (Zadoks, 1985). When there is a change among the policyholders or within the government, a new threshold is created due to new ideas about what it should comprise (Davies, & Mangan, 2005). In addition, decisions on risk thresholds and coverage limits are affected by demands for insurance and can be subject to political negotiations between decision makers and stakeholders.
- The literature shows an ongoing engagement in the concept and definition of thresholds (O'Mahony et al., 2014). In the agricultural sector, the question of how thresholds are defined has a direct influence on who bears responsibility for the event and who compensates for it. Old threshold conditions for compensation are thus no longer relevant, and there is a need for an insurance threshold framework that

will provide new insights for the range of thresholds options available and shed light on the process of setting them (Weingärtner et al., 2017).

- Thresholds can be applied to a variety of realms, i.e., areas of activity or interest that include thresholds applicable to the fields of climate, geography, and socioeconomics (Building block #1). All realms are affected by the exposure of society, government, and insurance companies to risk, while the geographic and socioeconomic realms are also affected by a society's sensitivity to risk.
  - The first realm includes thresholds pertaining to *climate fluctuation*: changes in precipitation, temperature, meteorological data, seasonal and general climate – all of which define society's exposure to a disaster. It is applied when a certain physical threshold is exceeded and, as a result, communities become vulnerable and the insurance is activated.
  - The second realm, *geographic location*, includes a threshold relating to the distance from the extreme event and from the risk zone in which the event occurred. This means that the insurance is activated when a certain physical proximity to a hazard, such as a flood, is crossed.
  - The *socioeconomic* realm relates to the social and economic aspects of the damage (Changnon, 2007) and the society's sensitivity to a disaster. Setting a threshold based on socioeconomic conditions implies consideration of factors such as the insured individual's ability to cope with a disaster.
- Building block 2 delineates the criteria for acceptable risk for the different insurance realms. There are two types of thresholds: *deviation from average* and *upper or lower limit.*
  - The *deviation from average* threshold is used in the climate fluctuation realm, especially regarding precipitation and temperature change disasters.
  - The *upper or lower limit* threshold is mainly used for the geographic and socioeconomic insurance realms. An upper limit refers to a limit above which compensation will not be paid and below which there is an acceptable risk and compensation will be paid.
- Building block 3 addresses ways of operationalizing the primary thresholds. The risk indicators depend on the previous choice of building block.
  - The first risk indicator is *magnitude of variance,* in other words, the variance can be large or small, over different periods, and with different effects. This risk indicator often addresses the *deviation from average* primary threshold and is applied to the realm of climate

insurance. It is often measured using two sub-risk indicators: *short-term high deviation* and *long-term low deviation*. In the case of the former, the insurance is activated only after experiencing great discrepancy from the average for a brief period of time. Long-term low deviation, on the other hand, is defined by extremely low temperatures ranging from 2°C to 3°C above the average and long term would be experiencing this throughout the whole summer (Changnon, 2007).

- The second risk indicator refers to a disaster taking place either during or beyond the *growing season* and belongs to the climate realm.
- The third indicator also belongs to the climate realm and relates to the *age of the crop*, i.e., given an extreme event, the insurance is only activated if the crop has been growing for a specific number of days.
- The fourth indicator is *geographical difference,* referring to an area's suitability to a certain crop.
- The fifth risk indicator is *distance* from the disaster. This belongs to the geographic realm and describes damage that takes place in an area of high risk.
- The sixth risk indicator is the *extent of the damage*. This belongs to the socioeconomic realm and is a combination of a society's levels of exposure and sensitivity and often specifies a minimum amount of damage after which the insurance is activated.
- The last risk indicator is called *mitigation tools*. This risk indicator addresses the need to implement disaster prevention measures in order to be eligible for insurance. The mitigation tools are a function of policy regulation on the one hand and requirements of insurance companies on the other. This risk indicator often addresses the *upper or lower limit* primary threshold and is activated via two risk indicators: *conservation and maintenance status,* and *effectiveness*, which both relate to the socioeconomic realm. Regarding *conservation and maintenance status*, an area is only insured if measures have been taken to guarantee that it is in good, usable condition. Regarding *effectiveness*, it is not enough to take precautionary measures to prevent the disaster; these measures must also be above a lower limit of effectiveness.

Trajectories of threshold

- The threshold framework outlines choices of compositions which each lead to different insurance contracts. This pick and mix composition establish three main trajectories (see Figure 1). Each trajectory is constructed according to the set of building blocks and often differ in their definition of the disaster and how this definition is embedded in the insurance mechanism.
- The first trajectory is the *climate exposure trajectory*. The *climate exposure trajectory*, belonging to the climate realm, can be related to extreme temperatures, extreme precipitation, and the timing of the disaster, for example, the timing of the event during the life cycle of the crop. In some cases, it has been seen that the climate exposure influences how a disaster is defined (which shapes the conditions for activating the insurance) and the actual insurance contract.
- The next trajectory is the *sensitivity trajectory* is based mainly on the society's sensitivity to a disaster and belongs to the socioeconomic realm. This trajectory requires the society to take certain actions in order to minimize the damages and thus be eligible for insurance. This trajectory has been used in defining a disaster (in a disaster training program in the United Nations) as "a serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the capacity of the affected society to cope using only its own resources" (cited in Sivakumar, et al., 2005, p.2).
- The last trajectory, the *location exposure trajectory*, belongs to the geographic realm and is situated on the continuum between exposure to the disaster event and the society's sensitivity. In this case the threshold is a function of geographical proximity to the extreme event. This trajectory has both a geographic dimension, which captures changes in the physical conditions, and a social dimension, as farmers often have a choice of where geographically to practice agriculture.
- The conceptual model differentiates between several drivers for change in insurance thresholds. These include the external physical elements that establish the exposure of the society to a disaster, the sensitivity of the society to a disaster, which is a function of its socioeconomic conditions and mitigation measures taken by the insured, and cases that include both exposure and sensitivity such as the trajectory that is based on proximity to the disaster. Changes in these drivers may change the choice of the building blocks and thus establish a new threshold trajectory.
- The archetype in the research also seeks to capture political considerations for choosing the trajectory and threshold. In the face of a disaster event, countries often declare a state of disasters triggered by

natural hazards which may define the possible boundaries of a threshold. Declaring a disaster triggered by natural hazards is always the political decision of the country's regulator, who is responsible for overseeing the choice of each of the building blocks and updating them. The regulator can also become sensitive to political agendas, budget availability, and the desire for popularity, leading to suggestions that governments may be more inclined to grant compensation just before elections (Bouwer et al., 2007).

- Another angle demonstrating the political consideration of the regulator is the role of government subsidies in supporting insurances.
- Figure 1 attempts to demonstrate how changes in the drivers shape the fluctuations in supply and demand for insurance contracts and how these affect (and are affected) by thresholds conditions and hence shape the design of the insurance contract. Indeed, insurance companies have recently been struggling with the growing number of claims relating to disasters triggered by natural hazards, which demonstrates a growing demand for insurance too (Lamond & Penning-Rowsell, 2014) and affects the design of contracts. A growth in claims could also lead to further limits on the supply of insurance or could destabilize insurance markets.

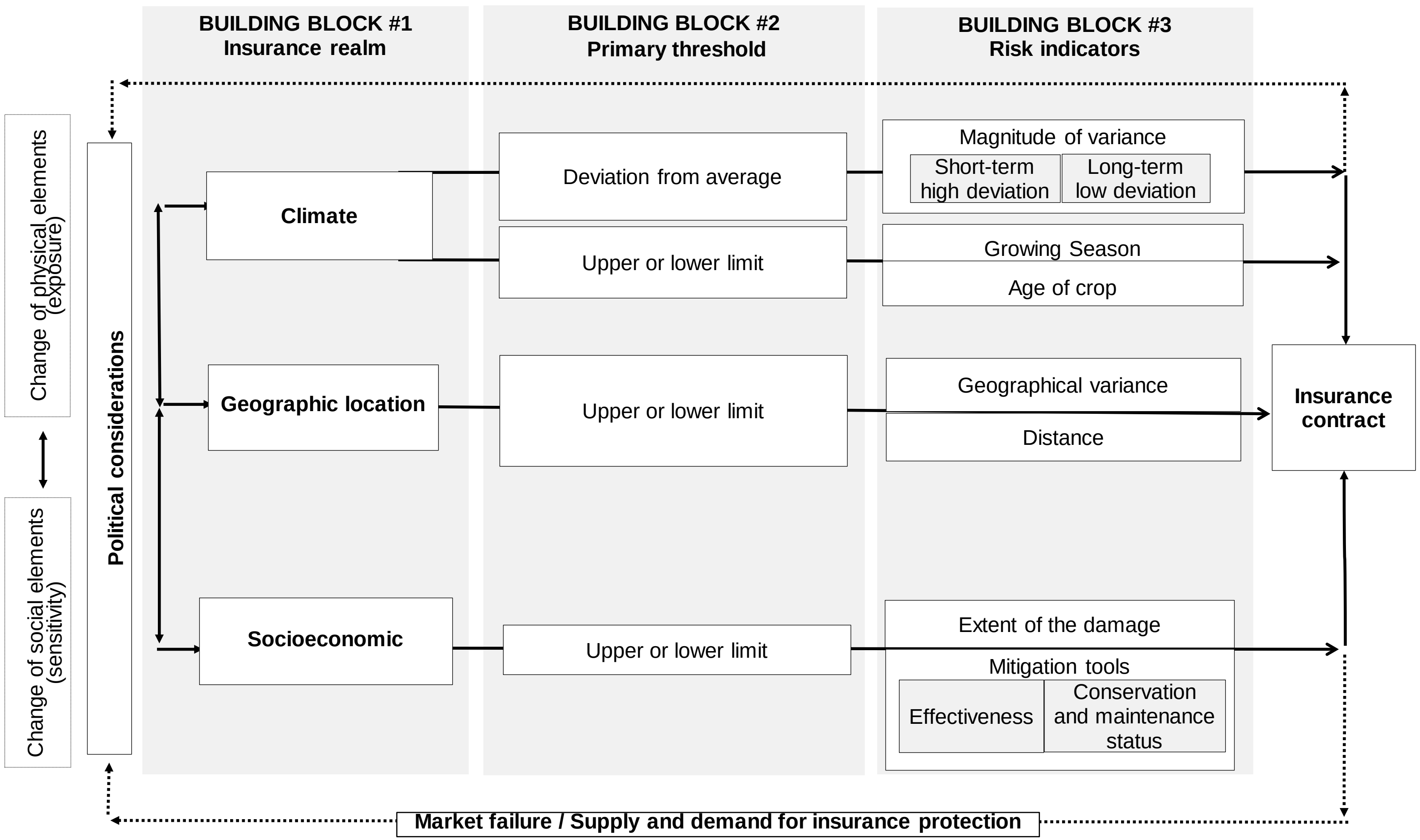

Figure 1: An archetype for choosing disasters triggered by natural hazards insurance thresholds

Utilizing the theoretical model

- Data was taken from insurance contracts over the years 2010-2020 (a total of 10 contracts). The insurance contracts were taken from ‘Kanat’-the Israel Nature national Fund for agriculture.
- Nine main crops belonging to the vegetable industry were chosen. Each crop has a few sub crops which were chosen leading to a total of 30 sub crops used in the research.
- Some sub crops were chosen with a high-risk index and some with a low-risk index to be used as a control group.
- Data analysis was done by counting the number of threshold references and the percentage of change of references for all 9 crops over time and by finding the changes over time in the definition of the insurance threshold.

IV. Results

- Building an insurance threshold archetype. The core building blocks of the archetype reassembles them into three plausible trajectories.
- There is a variety of thresholds
- Insurance thresholds designing the insurance policies are seen in the case study in different frequencies in time and space. They are increasing along time and their presence vary as a function of the insurance realms risk.
- The results of the research bring up new insights into what is considered a risk in an insurance.
- Background conditions for changes: Vulnerability (exposure, and sensitivity of society); political involvements; Social and physical conditions as governance function
- Not all insurance threshold tend to appear or change in a similar manner along time. They differ among different crops and among crops with different risk indexes. Thus, thresholds belonging to high-risk sub-crops tend to change more than thresholds belonging to low risk sub crops
- The sensitivity trajectory is more sensitive to changes among high-risk index crops.
- The thresholds change among all crops in a similar trend. This trend shows improvement in the insurance terms by making the insurance policy more friendly and easier to use by the insured farmer.

V. Recommendations

- Allow the insured and the insurer to know what thresholds are available for them, what is recommended to use and give a behavioral forecast of natural disaster insurance.
- Threshold conditions as a research agenda:

- Selecting a building block and choosing a trajectory of threshold conditions.
- Is this a function of background conditions or is there a dependency or is it a window of political opportunity?
- The implications of each choice of trajectory for policyholders and insurers

VI. Publications

- Under review-Climate risk management Journal

VII. Conferences

- The 60 Geography association conference, 29.12.2019, Haifa University
- 2nd Interdisciplinary Israel-TUM (Technical University of Munich) Winter School, Climate and Energy Policy in an Era of Technological Change, winter school, November 2018