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# An Integrative Collaborative Project Approach to Climate-Change Resilience and Urban/Regional Sustainability for the Mexico-Lerma-Cutzamala Hydrological Region

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## Abstract

In a rapidly urbanizing world, the social, economic, and ecological complexities of cities require conceptual and operational innovations to enhance climate resilience and sustainability. We describe our Integrative Collaborative Project (ICP) approach to co-create climate resilience in the Mexico-Lerma-Cutzamala Hydrological Region (MLCHR). In recent years, it has suffered from frequent natural disasters, and under climate change scenarios, the intensity and frequency of extreme events, including severe floods, droughts, heat waves and landslides are expected to increase. ICPs are framed as socio-technical capacity building enterprises, with networks operating at multiple scales. The approach differs from other integrative efforts, which tend to be top-down with scant civil society co-ownership, and focus on limited aspects like indicators/assessment, or institutional capacity building. We reimagine all operational stages, from creative thinking, through ethos and concept, assessment, planning, project design, implementation and management, and monitoring and evaluation. The design of ICPs is informed by six integrative domains: 1) project ethos, concept, and framing; 2) sectors, topics, and issues; 3) spatial and temporal scales; 4) stakeholder interests, relationships and capacities; 5) knowledge types, models and methods; and 6) socio-technical capacities and networks. Empirically, the approach is based on participatory development practices, pilot project work tackling sustainable water and sanitation in Mexico, and a synthesis of rich experiential knowledge spanning 20 years.

The theoretical basis considers a pragmatic knowledge frame, socio-technical transitions literature, and education for social transformation. We describe forward-looking operational details of the Pilot ICP for the Mexico-Lerma-Cutzamala Hydrological Region, with our three-university partnership as catalyst, and a new breed of socio-technical enterprise organization as a key partner, engaging stakeholders at municipal and regional scales.

## Keywords

Climate-Change Resilience, Sustainable Development, Urban, Regional, Mexico City

# 1. Introduction

## 1.1. Global Context

The year 2007 marked a threshold in human history: for the first time more people lived in urban than rural areas [1]. Analysts project that by 2050, two thirds of the world's population will be urban dwellers [2]. Rapidly developing cities—where political power is stratified and sustainability challenges are chronic and pressing even before considering climate change—exemplify the contemporary challenges that face development efforts to improve human well-being in the context of a changing climate. At the same time, cities can play an important role as sites for learning how to improve climate resilience through socio-technical innovation [3], and, as shown by the C40 initiative [4], they provide a practical political scale for diverse stakeholders to collaborate. The working definition of climate-change resilience we use for this paper considers the question: resilience of what, to what, and for whom? We define it as the capacity of a given socio-ecological system to do two things: a) anticipate, mitigate and recover from adverse climate-related impacts in ways that promote social justice/equity, economic vitality, and ecological integrity; and b) to undergo positive socio-ecological transformations that increase the adaptive capacity of the system over time. Notwithstanding, in any given setting—such as the Mexico-Lerma-Cutzamala Hydrological Region (MLCHR) pilot project we are envisioning—the stakeholder collaborative will define resilience and sustainability in ways meaningful to it, in its own socio-ecological contexts, informed by accepted resilience and sustainability principles. There is much to learn through comparative studies of the strategies adopted by cities across a variety of contexts and their ability to anticipate and respond to a wide range of climate-related challenges [5].

Translation and transfer of experience within and across regions require an integrative framework to serve as grounds for comparison. However, urban development often subscribes to conventional paradigms that reinforce business-as-usual approaches. Investments in technology consistently outcompete those in social innovation, holding that technology is the key to more sustainable, climate-resilient

cities, but forgetting that technologies, practices and policies are socially constructed. Urban design/planning is typically an expert-driven, top-down process that favors elite groups, privileges Western scientific and technical knowledge over indigenous and place-based knowledge, and offers only tokenistic opportunities for public participation [6] [7]. The complexity and uneven impacts of climate change require inclusive, socially innovative policies and practices. In many cities, low-income neighborhoods are disproportionately exposed to climate impacts, yet climate adaptation plans tend to promote the interests of those with wealth and political power [8] [9]. Drawing on the wider critical literature on participation in development, we argue that the emphasis on climate resilience in city planning must respond to pre-existing and emergent injustices. Furthermore, we argue that existing approaches are compartmentalized along sectoral, professional, cultural and class lines, resulting in competing and ultimately inadequate responses to complex problems. There is a clear need for integration across these lines based on principles of resilience as well as social and environmental justice.

This paper offers a framework for an Integrative Collaborative Project (ICP) approach to enhance climate resilience for cities and surrounding regions, and frames the effort as a people- and place-centered socio-technical capacity-building enterprise. This approach draws on essential elements of existing approaches and combines them with empirical evidence and our own experiential knowledge [10] [11] [12]. The ICP lens provides architecture to move beyond assessment into all stages of project design and implementation. As action-oriented scholars, we envision universities playing a central role in integrating multi-stakeholder knowledge to inform climate-resilience policy and practice. Universities are embedded in their respective societies, attentive to nuanced relationships, and offer opportunities for integration of critical theoretical, scientific, organizational, political, and place-based expertise. We draw on the notion of education for social transformation, which recognizes education as a mechanism to integrate environmental concerns with efforts to enhance socio-economic justice [13]. In applying this approach to a case study of the MLCHR, we demonstrate its efficacy under conditions of hyper-complexity exacerbated by climate change.

The objectives of this paper are 1) to articulate problems with conventional urban and regional development practice in the context of a changing climate, and associated conundrums, 2) to describe the theoretical and operational architecture of an ICP approach and 3) to demonstrate how we are beginning to apply it in the MLCHR. This region includes Mexico City, neighboring cities of Puebla, Cuernavaca, Toluca, and Pachuca, and neighboring watersheds. We apply ICP architecture to reimagine all operational stages, from creative thinking, through ethos and concept, assessment, planning, project design, implementation and management, and monitoring and evaluation. ICP architecture considers six integrative domains to guide process and project design: 1) project ethos, concept, and framing; 2) sectors, topics, and issues; 3) spatial and temporal

scales; 4) stakeholder interests, relationships and capacities; 5) knowledge types, models and methods; 6) socio-technical capacities and networks.

## 1.2. Problems and Conundrums

We employ the ICP approach to respond to persistent problems facing development practice across many contexts, including the following:

- "Development" governance is fundamentally flawed: project design is driven by interests that extend beyond the places and people they are intended to benefit, and those interests often fail to engage those intended beneficiaries [14]-[19]. Top-down processes tend to yield outcomes that compound structural inequality and social inequity (e.g. [19] [20] [21]). Participatory development is not a new approach, is not a panacea, and has its own challenges in terms of whether or not it addresses power equities among stakeholders (especially civil society and central government) and whether or not it improves social and technical capacity to respond [14]-[21].

- The prevailing ethos of "development" elites is extractive in philosophy and approach. Even well-meaning efforts at integrated assessment and data-gathering can manifest as taking information out of a place [14]-[19].

- Despite decades of critique (most notably the work of [22] [23] [24] [25]), development practice remains biased toward powerful technologies and technological "solutions"; the vital social dimensions of development—notably participatory governance that puts affected communities at the center of efforts—is missing.

- There is insufficient attention paid to the need for capacity-building on a societal scale, both in order to understand complex socio-ecological issues, and the consideration of responses to them that embody the sustainability principles of social justice, intra- and inter-generational equity, economic circularity and ecological integrity [10] [11].

The ICP approach responds to three conundrums we have previously articulated elsewhere [12] [26]:

- **Socio-ecological complexity conundrum**: Dynamic socio-ecological systems are intrinsically complex, comprised of multiple components linked together with strong feedback loops. Making models too complex may lead to confusion for managers, communities, and policy makers, and data gathering may be too burdensome. Einstein's principle [27] provides guidance: "A scientific theory [model] should be as simple as possible, but no simpler". We ask: How can essential elements of an urban/regional system be modeled and presented simply enough to be realizable, accessible and useful to stakeholders, without over-simplifying and losing validity?

- **Varying spatial/temporal scales conundrum:** Spatial scale presents challenges—but also opportunities—for urban/regional projects. How can urban development operate at an appropriately large scale to capture relevant dynamics (e.g. hydrology, stocks/flows of people), while remaining responsive

at smaller scales? Considering regional as well as local scales is transformative because it radically changes the scope of design, e.g. several inter-connected cities vs. just one city on its own, capacity building serving towns, cities and the region. On the temporal side, projects tend to use one timeframe—e.g. 30-year design life for a power station, 5 - 10 years for neighborhood revitalization—while social and ecological cycles may be happening over much shorter timeframes. Sustainable development has challenged traditional planning horizons by calling for the consideration of generational timeframes: forcing us to plan 25 to 50 or even 100 years ahead. How can we attend in parallel to urgent short-term, medium-term and related long-term goals, while adapting to changing needs and conditions?

- **Stakeholder diversity conundrum**: Socio-ecological systems at varying scales comprise diverse stakeholders, and urban/regional development projects impact them unevenly. How can resilience projects accentuate positive impacts, mitigate negative impacts, reduce inequities, be responsive to stakeholder diversity, and leverage this diversity in the form of human, social, manufactured and financial capitals [28] to build stronger socio-technical capacity at a societal scale?

## 2. ICP BASES

### 2.1. Empirical Base

The ICP approach has origins in the participatory development efforts of numerous scholar-practitioners [14]-[21], and considerable efforts at integrated assessment, such as the Millennium Ecosystem Assessment [29], UNEP's Global Environment Outlooks (GEO) [30]. The empirical basis for the ICP approach presented here grew out of sustainable development assessment and planning work we conducted on water and sanitation (WATSAN) systems in Mexico from 1998-2000 [10] [11]. Downs facilitated a "top-down-meets-bottom-up" process with multiple stakeholders—civil society groups, universities, government agencies, businesses, and donors—in three cities: Ciudad Juárez, Chihuahua (1.3 M people in 2010); Atizapán de Zaragoza, MCMA (0.49 M in 2010); and Mérida, Yucatán (0.78 M in 2010). Our goal was to co-create the social and technical capacities necessary to enable a sustainable WATSAN system. We were able to successfully navigate mistrust and unfavorable power dynamics—especially between the federal government agency and civil society groups—by creating an open, horizontal process; the United Nations University was the facilitator of the effort and was seen as a reliable, independent entity who could be trusted. Notably, in Juárez, the social capital the stakeholder collaborative assembled was sufficient to mitigate corrupt attempts by special interests to take control of the effort. The guiding ethos of this early ICP project was that sustainability depends on a transparent assessment and planning process to which all stakeholders contribute, lending their own capacity, and receiving the tangible benefits of collective capacity building by the group [10] [11]. On reflection, the key ingredients of

success were: a) water was a galvanizing "gateway" sector that impacted all stake-holders in powerful ways; b) the capacity-building enterprise recognized each stakeholder group, worked to incorporate groups into the project, and valued their contributions; c) the transaction costs of collaboration were significantly out-weighed by the tangible benefits of active collaboration; d) our activities built trust and mutual respect over time.

Our ICP approach also arises from a critical synthesis published in 2017 [12]. We used empirical evidence (see [1] [10] [11] [31]), five IPCC Assessment Reports since 1990 (incl. [32]), experiences with two global environmental assessments (the Millennium Ecosystem Assessment and GEO-4), as well as climate-change policy experience [33] [34], and our own experiential knowledge.

## 2.2. Theoretical Base

Theoretically, ICP rests on four bases: 1) a pragmatic knowledge frame; 2) participatory development approaches dating back to the 1980s; 3) socio-technical transitions; and d) education for social transformation.

Epistemologically, we use a pragmatic knowledge framework that argues knowledge arising from actions and their consequences, focusing on solutions to problems, is a welcome alternative to the positivist approach [35] [36] [37]. Approaches to understanding complex problems and their contexts based on so called "expert-driven" positivist scientific methods have been unable to contribute much to an action agenda for marginalized people. The field of common-pool resources provides a mainstay for our approach: it investigates institutional predisposing conditions for successful local governance of common property natural resources [38]. The ICP approach centers on collective capacity building among stakeholders, that has gained traction since 2000 [39] [40]. For example, Koontz and Johnson [41] showed that multi-stakeholder participation in watershed projects in Ohio, USA, stimulated the creation of strategic plans, the prioritization of issues, and social capital development. Experience of participatory development approaches has shown that active participation by stakeholders in transparent analysis and planning stages can engender a sense of ownership and trust of the policy-making process [14] [15] [16]. Used for over 30 years by development practitioners, these approaches employ methods—e.g. participatory rural appraisal (PRA), participatory action research (PAR), rapid rural appraisal and participatory action development—to better incorporate the voices of those development targets (usefully summarized in [42] [43]). Leal [17] argues that participatory development emerged from PAR, which itself draws upon thought such as Freire's emancipatory pedagogy. Whereas PAR sought to make visible the structures that produce poverty, and in so doing empower people to transform those structures, participatory development more often used various approaches to identify issues within these structures that might be addressed through external intervention. Despite significant efforts to create transformation within development practice [14] [15], experience cautions against the naive use of par-

ticipation to inform project design and implementation, as participation is a term open to a range of interpretations and uses, many of which avoid confronting underlying structural challenges. Resulting shallow participation makes the input of people directly impacted by projects circumscribed in a manner that elides disagreement while legitimizing the plans of the wealthy and powerful (e.g. [17] [18] [25]). The ICP approach we propose focuses squarely on structural factors that produce challenges, and the need to address those structures not primarily through external action, rather by empowering local and regional partners to co-create resilience. Similarly, community based water management experience provides another theoretical and empirical foundation (see [44] [45] [46] [47]; among many).

There has been considerable attention paid to the need for integration of social and technical innovations. Socio-technical transitions literature holds that societal and industrial transformations lead to a more sustainable human-environment relationship [48] [49] [50] [51]. Transitions for these scholars encompass technologies and market shifts, user practices, policy discourses, and governing institutions. There are two main threads to the transitions literature, the Technological Innovations Systems (or TIS) approach and the Multi-Level Perspective (or MLP). The TIS approach comes out of the innovation literature and focuses on the broad set of actors and institutions that influence innovations in transition technologies. The MLP began as a critique of the TIS, suggesting that it conceived of the broader innovative ecosystem too narrowly (c.f. [52]). The MLP looks beyond particular technology towards robust configurations that sustain new approaches over time. Carvalho *et al.* [53] explicitly took the concept of space to the transition literature. In their study of three cities, Göteborg, Sweden, Hamburg, Germany, and Curitiba, Brazil, they examined the transition to "green" automotive transport through a spatial lens. They were able to go beyond basic national policies to show how innovations could extend beyond technological development objectives and finance incentives to social learning and innovation. Dewald and Truffer [54] examined the adoption of photovoltaics in Germany. In their study they found that influence extends beyond the national scale to the local scale of governance, NGOs, and other actors and institutions at the regional scale proved very important. Hodson and Marvin [55], in their study of energy transitions in Manchester, England, showed that diverse actors, institutions, and networks set the stage for the three operant concepts, niches, regimes, and landscapes, of the MLP. These approaches and have been well-documented in the transition literature (see [56]).

Despite the vibrant nature of this work it has made certain conceptual commitments over others and there is room for additional friendly amendments to the approach. In particular, Coenen *et al.* [57] call attention to the neglect of by transition scholars of the spatial features of socio-technical transitions. "In particular, transition analyses have overlooked where transitions take place, and the socio-spatial relationships and dynamics within which transitions evolve" ([50]

p. 969). The existing literature remains insufficiently equipped to assess the advantages, conflicts, and tensions that are constituted by the economic, institutional, social and cultural, territories in which transitions are embedded except as passive contexts [51].

Transition studies have also benefited from critical examinations from other conceptual perspectives. Lawhon and Murphy [56] critique MLP transition studies through the lens of political ecology, examining features beyond the national scale. In particular, they argue that there is no single scalar driver of innovation; they are broader causally linked social and economic processes. Employing the concept of "competency groups" they show how broad sets of actors influence socio-technical transitions. For political ecologists, knowledge is uneven in societies, it is often not "right" or "wrong" (indigenous voices), and is ultimately produced by multitude of voices or coalitions, such competency groups. Finally, Lawhon and Murphy ([56] p. 367) introduce the concept of power relations. Through the concept of governmentality they elucidate how "social movements, in different places, create narratives and discursive frames to mobilize actors for the realization of a desired outcome".

Our university partnership to promote the ICP approach in MLCHR and beyond is grounded in social justice and the philosophical underpinnings of Education for Social Transformation (EST) [13] [58]. EST explicitly challenges the unjust mechanisms that have historically marginalized peoples and societies, even within seemingly noble attempts to address ecological challenges. At the root of EST is the notion that environmental discourses that employ education, such as "education for sustainable development", must do so for more than just economic utility and expedience, as frequently occurred [59]; rather, such concepts must emphasize socio-economic and environmental equity in the effort to address both human material needs and the limits of ecological exploitation [13] [58]. First, EST is rooted in critical social intellectual traditions that advance "fairness in a 'good' society" through education [60]. In this context, education's social justice agenda examines, and seeks to rectify, how social inequalities are generated through socially constructed traits such as race, gender, class, sexual orientation, and "difference" in general. Second, its more recent environmental concern emerges from a critical view of the longstanding utilitarian links between education and the environment in which education was seen as largely complicit in the commodification of the ecosystem for unchecked capitalist consumption [13] [59] [61]. Its current environmental component aims to "generate active support for environmental protection and the attainment of a more sustainable balance between human activity and the natural ecology" [58]. It is within EST's critical framework that we invoke the importance of universities within an ICP approach. We posit that universities have the necessary organizational, scientific, societal legitimacy and deep connections between multiple sectors, communities and regions to facilitate the level of integration needed. Additionally, as institutions designed in service of human advancement in all forms,

social equity is inherently part of the university mandate.

## 3. ICP Model

Based on the aforementioned empirical and theoretical underpinnings, the ICP approach is a scalable socio-technical capacity building enterprise that contemplates six *integrative domains*: 1) project ethos, concept, and framing; 2) sectors, topics, and issues; 3) spatial and temporal scales; 4) stakeholder interests, relationships and capacities; 5) knowledge types, models and methods; 6) socio-technical capacities and networks. We apply this integrative thinking to all operational stages of a project (**3.1** below). We are using the MLCHR to operationalize the ICP approach, and to provide practical details (**5.0**).

### 3.1. Domain #1: Project Ethos, Concept, and Framing

The guiding philosophy and spirit of an ICP effort—its ethos—centers on igniting the imaginative thinking of social groups working together, and co-creation of our capacity to understand and respond to complex problems impacting us all, albeit in uneven ways. Project ethos, conception, and framing thus comprise the most important stage of any effort, setting the tone for all that follows. Einstein reminds us: "imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution" [62]. Business-as-usual projects tend to be top-down, driven by a minority of elite actors, tending to serve their interests and conform to their modes of operation. Civil society groups with the most to win or lose in resilience projects, are chronically marginalized from the project design process. Compounding the bias, community concerns and indigenous, local knowledge are devalued compared to dominant scientific-technical framings of development [19] [63] [64]. This approach shows a strong bias that impedes sustainable development in urban, peri-urban and rural settings[1] [see] (for example [19] [22] [23] [24]). A growing literature on socio-technical transitions [65] and sustainability science [66] challenges conventional modes.

Conceiving, framing and designing resilience work in integrative ways goes well beyond conventional project design. It requires thoughtful consideration of the entire multi-stakeholder process, and how work stages interrelate (**Figure 1**): 1) Creative Thinking and Imagination—unfettered "blue-sky" ideas; 2) Concept and Process Design—ethos, approach and framing of resilience work; 3) Integrated Assessment[2]—identifying needs, characterizing baseline conditions to inform planning; 4) Integrated Planning[3]—visioning sustainable futures, comparing

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[1]It is also necessary to think beyond the terms "urban", "peri-urban" and "rural" to recognize the continuum of the socio-ecological setting in which towns and cities are situated, and inter-dependencies therein (see also Domain 5: Temporal and Spatial Scales).

[2]Integrated assessment is very different from conventional project-driven assessments. It serves the larger questions: What is happening to socio-ecological systems? Why is it happening?

[3]Integrated planning answers: How can we respond? It combines aspirational visioning with deliberative, impact assessment tools to compare options.
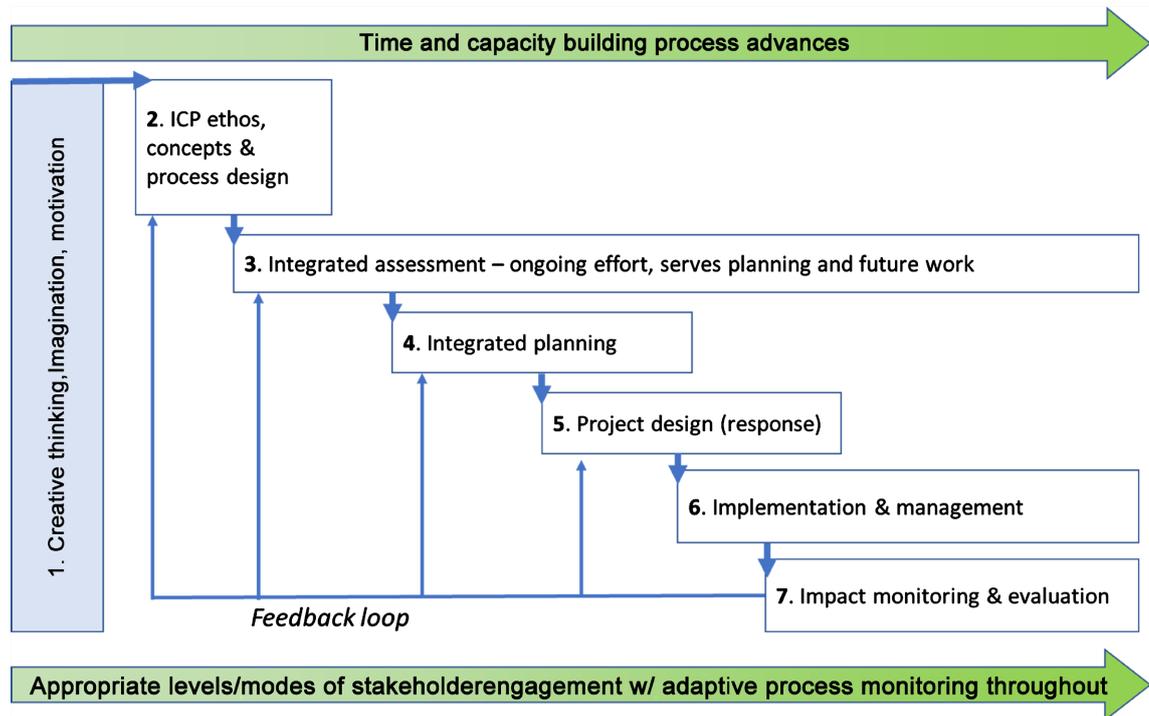
**Figure 1.** ICP operational stages. The collective imagination of stakeholder partners sparks the effort. Stages are strongly interrelated, with integrative domains informing each stage, and feedback imparting adaptive response capacity. Stages 1 - 3 govern the process. Stakeholder engagement is an ongoing driver, using different modes and levels.

project alternatives using impact criteria, choice of preferred project; 5) Project Design—detailed activities and outcomes, timelines; 6) Implementation and Management of the Project; and 7) Impact Monitoring and Evaluation[4]—gauging project impacts, changing needs and conditions, re-informing assessment and planning for adaptive response and future efforts to improve existing projects and/or the development of new projects.

### 3.2. Domain #2: Sectors, Topics, and Issues

Integration across multiple sectors, topics and issues—e.g. water supply and sanitation (WATSAN), energy systems, food and agriculture, transportation, health—is worthy of emphasis in resilience practice. Sectors are strongly interrelated in terms of stocks and flows materials, energy, information, people, money, and other types of capital. Models depicting these stocks and flows are important for sector integration and can be built collaboratively. Gateway sectors are those that resonate with stakeholders (health, water, food) and can serve as entry points for discussion of complex interrelated systems, including climate-change deliberations for resilience work. Similarly, keystone sectors (e.g. water, energy) enjoy influence over multiple sectors, and progress on the resilience and sustainability of these

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[4]Impact Monitoring and evaluation ventures well beyond the accounting model that primarily serves donor interests—here it is an integral part of the ICP approach, feeding-back to inform assessment and planning.

have major positive impacts on socio-ecological systems. In prior work, [10] identified water supply/water resources as a keystone sector, with the highest influence on other 17 topics of the 1992 Agenda 21: Blueprint for Sustainable Development. Resilience theory forces us to pay attention to the interconnectedness of socio-ecological sectors, and consider how systems buffer and recover from shocks and stressors at local and regional scales [34] [67]. Resilience indicators are among the most important to consider during assessment and planning stages (Figure 1).

### 3.3. Domain #3: Spatial and Temporal Scales

The spatial scales used in resilience shape that work profoundly: local, watershed, multi-watershed, regional, and national scales pertain. Populations and landscapes are part of a biophysical continuum, with interdependencies and multiple connecting flows of all types of capital—natural, human, social, financial and manufactured. Given that levels of co-dependency can be very high, the fates of towns, cities and regions are closely intertwined in the face of climate change, and the resilience of one depends on the others. Considering temporal scales, it is important to pay attention to urgent, short-term, needs (1 - 5 years); medium-term needs (5 - 25 years), as well as longer-term, inter-generational time-frames (25 - 50 - 100 years). Stakeholders articulate differences in priorities, both in space and time. For example, local politicians may operate primarily on a 3-year election cycle, so adopt the short-term view; investors may worry about short-term shifts in stock prices, while businesses plan strategically for the medium term. IPCC scenarios project to 2100, and the sustainable development paradigm has a guiding principle of both intra- and intergenerational social equity. Thus, resilience work must pay attention to multiple overlapping spatial and temporal scales, recognizing they are inextricably linked.

Fundamental to the socio-ecological complexity conundrum (**1.2**) is that social and ecological components are spatially and temporally dynamic. Pressures and drivers may be acting at the national scale, while the impacts are felt at the regional and local scales. Climate change is on a global scale, but the impacts are uneven by locality. Similarly, development projects yield positive and negative impacts that are highly uneven and often inequitable. During assessment and planning stages, it is important to pay close attention to the projected distribution of positive and negative impacts across a landscape and among demographic segments of a population. Modeling spatial impact patterns relies on GIS analyses such that climate resilience efforts confront places that are most vulnerable (e.g. flood zones) and distribute the positive and negative impacts of development projects more equitably.

### 3.4. Domain #4: Stakeholder Interests, Relationships and Capacities

The question of how human capital and social capital can be strengthened and

mobilized sits at the core of successful ICP approaches, which leverage social and technical innovations [11] [12]. Participatory, bottom-up development practice was a response to top-down processes in the 1980s (see, for example, [14] [15] [43]). On their own, however, they have been insufficient to counter conventional modes [17] [18] [19] [68] [69] [70]. Calls for ICP-type modes, where bottom-up meets top-down approaches, are strongly advocated by the United Nations and others [1]. An ICP approach holds that the needs, alternative responses, impact criteria by which they are compared, and enabling capacities, are deliberated and acted upon collectively by stakeholders.

Who holds political power, from whence it originates, and what influences the ways it is wielded becomes part of understanding baseline conditions and contexts for knowledge and action [19] [71]. Political ecologists, political economists and anthropologists have much to contribute in this regard. While uneven political power is the norm—even in democracies—climate change disruptions are challenging the status quo, creating opportunities for new and potentially transformative initiatives to tackle local and regional priorities. An ICP approach is adaptive (feedbacks of **Figure 1**) to socio-ecological disruptions and changes—in line with calls for adaptive modes [72] [73] [74] but its application to resilience remains nascent.

Functioning stakeholder relationships hinge on trust and legitimacy, but these are fragile and difficult to nurture [75] [76] [77]. They hinge on socially-innovative ICP-type processes: 1) efforts made to listen authentically to stakeholder concerns, and respond to them tangibly; 2) framing projects that are meaningful to diverse stakeholders and responsive to their needs; 3) dialogue that enables constructive, respectful exchange; and 4) a vibrant sense of shared project ownership, shared responsibility, and shared benefits that outweigh costs [10] [11]. The pooling and cross-fertilization of stakeholder capacities become the driving force for positive change.

### 3.5. Domain #5: Knowledge Types, Models and Methods

Three major knowledge gaps persist in resilience work: 1) weak or missing social science knowledge; 2) weak or missing local knowledge; and 3) weak integration among scientific disciplines and knowledge types [1] [10] [11] [33]. The life-blood of ICP work in the resilience arena is the flow of shared knowledge: indigenous; intra- and inter-generational; multi-, inter-, and trans-disciplinary; professional; experiential; and among diverse peoples and places. Knowledge partnerships are a theme of resilience and sustainability work [78] [79]. Participatory modeling is also gaining traction [80]. The ecological knowledge of urban communities is undervalued and typically excluded from sustainable development processes, whereas the knowledge of rural communities tends to have more weight based on the notion that rural people live closer to "natural" ecosystems. Furthermore, by emphasizing the context-specificity of such knowledge, researchers presumed that migration is associated with knowledge loss. However, a number of recent studies

reveal the significance of ecological knowledge to urban communities, including recent arrivals to megacities [81] [82]. Urban, rural and regional ecological knowledge—a primary ingredient of ICP integrated assessment (**Figure 1**)—can serve as the basis for a democratization of resilience work.

Epistemological, educational and cultural trends reveal that specialization arises in a particular field (e.g. Engineering, Law, Medicine, Economics, Information Technology), with limited perspectives, framings, modes and models. Destructive competition within and among fields runs counter to the ICP ethos, whereas expansive, interactive modes are constructive. For example, in tackling burgeoning chronic disease linked to urbanization, conventional medical diagnosis and treatment modes are grossly inadequate. An ICP-type effort calls for attention to upstream drivers/risk factors such as polluted air and water; foods high in sugar, salt and fat; unhealthy, sedentary lifestyles; and ill-informed attitudes and behaviors—in close concert with the diagnose/treat model.

### 3.6. Domain #6: Socio-Technical Capacities and Networks

Rather than be limited by existing capacity, there is a need to innovate strongly on resilience practice by enhancing or building new capacities to support outcomes. Fundamentally, this socio-technical enterprise—expressed as an ICP—becomes the engine of urban/regional innovation. Each stakeholder partner contributes knowledge/capacity to the whole, and receives tangible benefits from its creation. Our WATSAN pilot work synthesized four sources of data to identify the requisite levels of socio-technical capacity building: a) a critical review of a sampling of WATSAN development projects undertaken globally, comparing a minority which had yielded sustainable development impacts, with those which had not; b) a comprehensive literature review of WATSAN capacity building efforts; c) three workshops, one in each pilot city with multiple stakeholder partners; and d) expert opinions and experiential knowledge garnered from others in our professional networks [10] [11] [12]. Six levels of capacity emerged: 1) political and financial seed capital to initiate and catalyze projects; 2) human resources, education and training, awareness-raising; 3) shared information and knowledge resources; 4) policy and decision making and governance (incl. laws, regulations, incentives); 5) appropriate technologies and infrastructure; and 6) enterprise development, especially the stimulation of local/regional sources of entrepreneurship, products and services, replacing seed financial capital. These levels are interrelated, and comprise a capacity building system (**Figure 2**). Each is broken down into discrete operational pieces during project development (**Table 1**). The same six levels are applicable to multiple sectors, e.g. food systems, energy systems. Framing ICPs as socio-technical capacity building enterprises is scalable, yielding a distributed knowledge and capacity network (**Figure 3**).

### 3.7. ICP Compared to Other Integrative Efforts

Previous efforts to theorize urban climate resilience have produced important
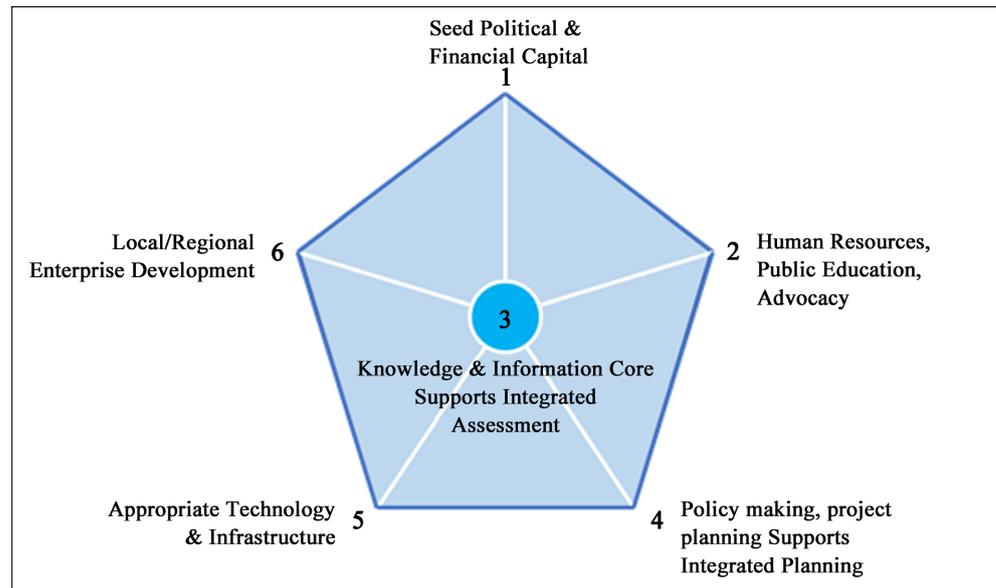
**Figure 2.** Six levels of socio-technical capacity. The levels are interrelated and comprise a system, connected by flows of information and the information core (source: Downs 2001 [10]).

**Table 1.** Operational components of the six levels of capacity building. Pertains to Domain #6: socio-technical capacities. ICPs will consider which components are relevant and of priority for a given setting (town, city, island, region) (adapted from [10]).

| Level | Examples of components |
|---|---|
| 1) Political and financial seed capital | • Mobilization of sufficient seed capital politically by gaining support of leaders at different levels (local, national, global), among diverse stakeholder groups. <br> • Mobilization of sufficient seed capital financially by gaining $ support from a diversity of sources (funding diversity mitigates the influence of one powerful entity). |
| 2) Human resources, education and training, public awareness-raising | • Education programs and curricula from Kindergarten through 12th grade. Engagement with teachers and youth through place-based learning. ICPs as learning platforms. <br> • Education programs/curricula in higher education. Place-based learning for students, engaged scholarship and practice for faculty. ICPs as learning platforms. <br> • Media, messaging and journalism about resilience issues to inform the public and policy makers. Countering of climate-change denial. Translation of science for public discourse. |
| 3) Shared information and knowledge resources | • Co-production of knowledge, shared information resources. <br> • Use of web-based, open-source GIS platforms that are populated by data from stakeholders, with QC/QA by academic researchers. Images and narratives included. <br> • Climate-change projections for each region are kept up-to-date, and impact implications. <br> • Existing sector systems (e.g. water, energy, transportation, health care) shown. |
| 4) Policy making, decision making and governance | • Policy making at local, regional and national levels are coordinated and share information and capacity (via #3). Decision-making processes are transparent, participatory (see **Figure 1**). <br> • Contemplates laws, regulations, incentives for innovation (e.g. energy innovation, water saving), equitable pricing of basic services (water, energy). |
| 5) Appropriate technologies and infrastructure | • Design and deployment, via process of **Figure 1**, of technologies and infrastructures that support sustainability of sectors like water, sanitation, energy, food and agriculture, transportation etc. <br> • Investment and creation of climate-resilient systems (new training from Level #2). |
| 6) Enterprise development | • Stimulation of local/regional sources of entrepreneurship, products and services, replacing seed financial capital in Level #1. <br> • Incentives for innovation from Level #4 drive local and regional efforts socially and technically. |
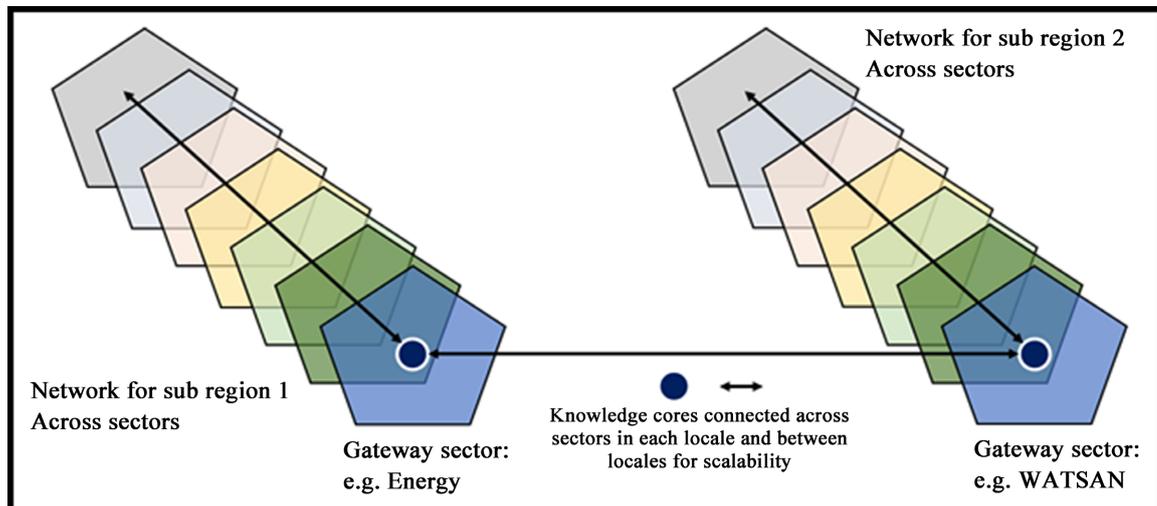
**Figure 3.** Capacity-building enterprise as a scalable socio-technical network. There are six levels of capacity for each sector, with information resources at the core of each (forming pentagons). Sectors integrate capacities at each level (e.g. Level 2: education and training across energy, water, food etc.), and connect via Level 3: the information resource core. Local and sub-region scale networks can be linked and scaled-up to regional and national scales.

insights regarding complexity and uncertainty. For example, Ahern [83] proposes that assessment of urban climate resilience should focus on multifunctionality; redundancy and modularization; biological and social diversity; multi-scale networks and connectivity networks; and adaptive planning and design. Jabareen [84] focuses on vulnerability analysis, prevention, urban governance, and planning for uncertainty, which can be quantitatively or qualitatively assessed at multiple scales. Another holistic approach is taken in the City Resilience Framework (CRF) [85], which considers a resilient system to be reflective, robust, redundant, flexible, resourceful, inclusive, and integrated. The CRF Index assesses these qualities according to 12 themes within four areas, namely health and wellbeing; economy and society; infrastructure and environment; leadership and strategy. Abdrabo [86] develops and applies an integrative framework to the challenge of sea level rise in the Nile Delta; not only does the analysis consider the physical system, socio-cultural and economic system, environmental quality, and institutional settings; unlike most other studies, the author examines linkages to surrounding rural areas and neighboring cities, which we endorse.

We compared six existing frameworks that focus on urban climate resilience to determine if they include explicit references to the six integrative domains of ICP. By our analysis, previous frameworks are limited in at least one of the following ways: 1) they focus on assessment and therefore measurable aspects of resilience, 2) they fail to consider resilience at multiple scales, including the relationships between neighborhoods, cities, and regions, 3) they do not recognize the value of incorporating diverse types of knowledge (e.g. scientific expertise and indigenous knowledge) into their capacity building efforts, and 4) although they acknowledge both social and technical processes, they do not link social

innovation and technology development.

The resilience framework proposed by Tschakert *et al.* [90] focuses on pre-emptive learning for climate change adaptation with rooted cycles for critical reflection, anticipation and response. The United Nations Environment Programme recently published its latest *Global Environment Outlook* report, GEO-6 [30]. GEO exemplifies global-scale integrated assessment, and has had some success in building in-country capacity through workshops [30] [91], and has integrated countries via regional assessment teams. However, there is little operational detail about how assessment informs other stages, and the roles for in-country civil society stakeholders and universities are limited; GEO, given its huge remit, is top-down in nature. The ICP approach can be used as an analytical framework for characterizing existing approaches, and revealing gaps that may need attention. Comparisons of several existing integrative urban resilience frameworks with ICP, in terms of integrative domains and operational stages (Table 2) and the operational stages are informative:

1) Integrated efforts by multilateral agencies (e.g. United Nations programs) often rely on coordination with national governments and are therefore typically top-down, with insufficient co-ownership by civil society groups.

2) Existing efforts tend to focus on one operational stage, e.g. integrated assessment, rather than all stages, thus limiting capacity building for resilience.

3) Integrative efforts struggle to work at multiple spatial and temporal scales in parallel.

4) Universities tend to play a consultative role in assessment and planning, therefore limiting their potential as catalysts for integrative collaborative enterprises.

One recent critique of the urban resilience agenda [92] highlights some of the

**Table 2.** Other integrated approaches characterized using ICP domains. Shows operational stage that is the primary application of the approach [83] [84] [86] [87] [88] [89].

| Framework | Primary Focus | Six Domains | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | | Ethos Concepts & Framing | Multi Sectors | Multi Scales | Multi Stakeholders | Knowledge Types | Socio-Technical Capacities |
| Ahern (2011) [82] | Conceptual | - | ✓ | ✓ | ✓ | - | ✓ |
| Collier *et al.* (2014) [86] | Assessment/ Case studies | - | ✓ | - | - | - | - |
| Jabreen (2013) [83] | Conceptual | ✓ | ✓ | - | ✓ | - | - |
| Abdrabo (2015) [85] | Assessment/ Case studies | ✓ | ✓ | ✓ | ✓ | - | - |
| City Resilience Framework (CRF) (2015) [87] | Assessment/ Case studies | ✓ | ✓ | - | ✓ | ✓ | ✓ |
| Meerow (2016) [88] | Conceptual Review | ✓ | ✓ | ✓ | ✓ | - | ✓ |

gaps we have identified, characterizing the City Resilience Framework (CRF) as exemplary of a global "urban resilience complex". While paying lip service to inclusion, a case study of Jakarta suggests the CRF reinforces the hegemony of governments and the private sector and marginalizes the interests of the most vulnerable communities. Efforts to enhance climate resilience require social innovations that integrate a diversity of stakeholders and knowledge types, including alternative conceptualizations of resilience rooted in local realities

## 3.8. Universities as ICP Catalysts and Integrators

The ICP approach is anchored by our own experiential knowledge as scholar-practitioners, and driven by recognition that the university's mission, societal positionality and power make it an excellent catalyst for socio-technical transitions and transformations. We thus posit that education, particularly through the role of universities, is integral to the efficacy of ICP work. As such, we propose that these educational institutions, which are embedded in the context of their respective societies, understand their nuances, and possess critical scientific and organizational expertise, are well placed to integrate multi-stakeholder knowledge to inform climate-resilience policy and practice. Thus, we are forming a partnership among our three universities in order to innovate teaching, collaborative research and multi-stakeholder practice to address urban and regional climate resilience and sustainability challenges. Provocative questions are fueling generative dialogue, among them: who decides "development" policies and practices? Is "development" working, and how do we know if it is, or is not? What do we actually know, and how do we know it? Where are the gaps in our knowledge? Is there a learning agenda, and if so who sets it? Can people use the information others create? What is the role of engineering and technology in development? How should we be educating our students? What is the role of the university in the face of 21$^{st}$ Century challenges?

In our socio-technical enterprise model, stocks and flows of information/knowledge, and exchanges and amalgams of capacity are the life-blood of an innovation network. They are sustained by vibrant, trusting and mutually beneficial relationships among the network members: the relationships among people are the "beating heart". This process constitutes education at the level of society—multiple stakeholders—or social learning [11]. The governing role of social learning in improving the relationships between humans and the socio-ecological systems they inhabit, impact and are in turn impacted by, has become a topic of growing importance [93]. Education is also a key component of the capacity building framework; it is a traditional focus of capacity building efforts, but its impact is magnified when it operates as part of an integrative, multi-level system [10]. Education has also historically viewed as one of the most effective means of social mobilization and the promotion of justice to marginalized groups. Innovative universities are uniquely positioned to both fulfill their traditional mission of education and research while at the same time acting as catalysts for resilience

work, and integrators across sectors, stakeholders, knowledge types and capacities. Academic programs—especially those at the graduate (MA, MS, MBA, MEng, PhD, DSc, DEng, DEd, etc.) level—can be re-imagined in this way using ICP principles and practices. The alumni of such programs are thus primed to become change agents in government agencies, NGOs, donors, and businesses, and may assume leadership roles that further ICP-based process and project design.

## 4. Mexico-Lerma-Cutzamala HYdrological Region (MLCHR)—Climate Resilience Context

### 4.1. Social-Ecological Context

We demonstrate the utility of the ICP approach by applying it to one of the most challenging urban contexts in the world: the MLCHR. We undertook early creative thinking on this specific application of ICP in 2017 [26], and we expand considerably here. The conundrums in this context are classic examples: 1) socio-ecological complexity is high due to coupled urban economies and hydrological basins; 2) overlapping spatial scales and temporal dynamics confound conventional approaches; and 3) stakeholder diversity is high, within a sociopolitical and economic system characterized by extreme power differentials, systemic corruption, and severe wealth inequities [9]. The Mexico City Metropolitan Area (MCMA)—the most populous urban area of the region by far—is located at 2240 m above sea level, on an ancient lakebed within an enclosed basin, the Cuenca de Mexico. What we are calling the "MLCHR" includes several major urban areas (**Figure 4**): MCMA[5] (population 21.2 M in 2014, [95]), and its neighboring cities of Pachuca (0.26 M in 2010, [96]), Puebla (1.43 M in 2010, ibid), Cuernavaca-Cuautla (0.49 M in 2010, ibid), and Toluca (0.49 M in 2010, ibid). The total urban regional population in 2010 was about 24 M. **Figure 4** shows some key socio-ecological aspects of our pilot region: projected population density 2020 (aforementioned major urban centers), state boundaries, watershed boundaries, rivers, and elevation.

Physical and demographic expansion of the MCMA began in the 1930s and peaked in the 1960s. In 1970, 11 municipalities were included in the definition of MCMA. The 1990s saw further expansion of urbanized area, and population density decreased due to dispersal from the city center. After 1990, expansion of the MCMA included formation of non-contiguous satellite communities. Currently, the MCMA includes 16 municipalities from the Federal District, one from the state of Hidalgo and 59 from the state of Mexico. With approximately 21.2 million people residing in the 4250 km$^2$, the MCMA faces a number of challenges [97] [98]. Growth of the MCMA in the 20$^{th}$ century was driven by migration from surrounding rural areas that changed and grew the urban environment. Population growth was highest in northern part of the city, leading to environmental degradation, including aquifer depletion, biodiversity loss, and carbon

[5]MCMA comprises a total of 76 municipalities [94], including the core Federal District (Distrito Federal or DF, 16 delegations, now officially called "Mexico City"/"Ciudad de México" since 2016).
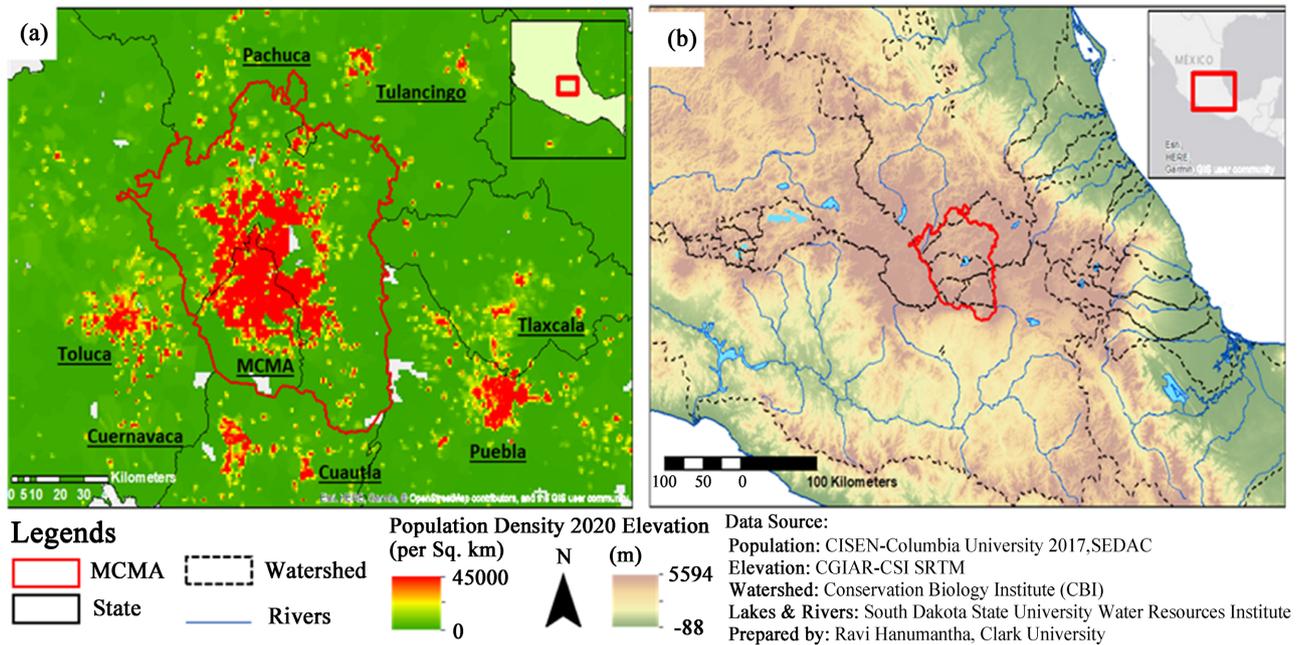
**Figure 4.** Population density and hydrology. (a) shows population centers of the region that are vulnerable to climate change, and need to build resilience capacity collectively. (b) shows topography, watersheds and major rivers.

releases. In addition, many informal settlements were built on hillsides, in flood-prone areas, and areas critical for aquifer recharge [99]. Natural flooding protection ended during the 1960s with construction of the "Great Sewage Canal" [100]. In the name of development, 80 km of rivers were used to build roads, resulting in a host of issues with the water supply. With increasing populations demanding water, massive hydraulic systems were built at regional level, including the Río Lerma and Río Cutzamala systems, which were built to transport water from outside of the Mexico City Basin [101]. Deep sewage systems were built in the 1970s to drain sanitation water from the valley [102] [103].

## 4.2. Climate-Change Impacts

Today, the location and socio-economic situation of the MCMA make it vulnerable to projected local impacts of global climate change in the near and far term. In recent years, the MCMA has suffered from frequent natural disasters [104]. The intensity and frequency of extreme events, including severe floods, droughts, heat waves and landslides are expected to increase. Under the IPCC A2 scenario, average temperatures are projected to increase between 0.5 and 2 degrees C for colder months and 2.25 in the warmer months by 2050 [99]. The Mexico City Climate Action Program has identified 5.6 million people who are particularly vulnerable to climate change due to their economic and educational status, gender, geographic location and other factors. One of the most worrying impacts of climate change in the MCMA is the projection that extreme rainfall will increase the number of flooding events. The region's sewage systems are already overwhelmed during intense rainfall and may be subject to further wea-

kening by earthquakes. Ponding of water during and floods during the rainy season has only minor direct economic impacts, but they severely impair mobility in the MCMA, resulting in significant economic losses [104] [105] [106]. Enhancing the resilience of MCMA requires infrastructure improvements to manage water during extreme precipitation events. On the other hand, the MCMA also faces more frequent droughts as a result of climate change.

From 2009 to 2011, drought in Northern and Central Mexico impacted the availability of drinking water, including some parts of the MCMA. Numerous tropical storms reduced the effects of the drought with increased levels in the reservoirs supplying water to the MCMA were reestablished [107] [108]. The frequency and magnitude of episodic rainfall and flooding in the MLCHR are projected to worsen [12] [109]; existing wastewater/stormwater systems struggle to cope, and the flood risk posed by a hazardous cocktails of untreated wastewater and stormwater is moving the city to major investments. In 2016, a very large anaerobic digestion wastewater treatment plant (WWTP) was constructed in Atotonilco, Hidalgo, 70 miles NNE and down-gradient of the urban center of the MCMA. In its first year of operation, it treated an average of 31.5 $m^3$/s and claims to be the largest WWTP in the world [110]. The new infrastructure also includes a major upgrade to the deep drainage system which will help evacuate stormwater and mitigate flooding. However, flood risks in some areas remain high and need to be assessed in a more integrated way. Tellman *et al.* [111] recently explored how the process of infrastructure development for WATSAN, driven by city government, can either reduce or augment flood risks because of complex system dynamics that require very careful consideration in the face of the ultimate exogenous stressor: climate change. Using a historical perspective spanning centuries, they found that: 1) endogenous risks change as the city expands, and they can increase; 2) a systems perspective is needed to avoid the amplification of risks, to better inform risk management; and 3) collectively people have far more agency in and influence over the complex systems they inhabit.

In the dry season, water scarcity has worsened as aquifers are further overexploited, and supplies are unable to meet demand. Unfortunately, the location of the treatment plant means it is not able to recycle treated wastewater to offset burgeoning water demand and scarcity, as we previously recommended [112]. More than ever before, efforts need to be made to treat and reuse wastewater, off-setting supply, and stormwater needs to be directed to recharge aquifers and reservoirs. Throughout the Mexico City Basin, extraction of water from the underlying aquifer is occurring at a faster rate than the aquifer can recharge. Recent estimates are that in the next 30 to 40 years, the Mexico Basin will cease to be the main source of water for MCMA [101]. Sustainable aquifer and water supply management is clearly an important dimension of resilience for the city. In response to climate change, Mexico's federal government has implemented numerous strategies, projects, and programs aimed at various sectors. For example,

the Mexico City Climate Action Program (implemented from 2014 to 2020) attempts to reduce the vulnerability of impoverished communities. Also, the strategy is to strengthen city programs and projects to build resilience [113].

## 5. ICP Pilot—Mexico-Lerma-Cutzamala Hydrological Region
## 5.1. Concept

We have initiated a partnership among our three universities to co-create an ICP Pilot Project to support MLCHR's climate resilience and sustainable development. The Pilot Project seeks to learn from experience what works and what does not, using an ICP-based approach. The successes and failures of this pilot effort will inform our ongoing and future collaborative work. As universities, we are using this approach to reimagine three aspects: 1) curriculum ethos and content in-line with ICP; 2) research projects that are people- and place-based, that become model ICPs; and 3) advocacy and public outreach for an ICP approach leading to a network of key stakeholders. For example, we are re-imagining the curriculum for students who are training for careers in development, environment and ecology, engineering and technology. The way we think about the pilot for the region is being informed by the ICP Domains (**3.0**), as well as envisioned operational stages (**Figure 1**).

What might this look like? How do we bring together students who are primed to learn, faculty who are eager to teach and undertake research that has positive impacts on people and places, and real people in real places who face considerable socio-ecological challenges? Beginning with *Stage #*1—imagination and ideas (**Figure 1**), we are conceiving a new field-school experience for students, one that combines teaching with people- and place-based research and practice. Students will work with faculty to identify 3 - 4 pilot municipalities in the MLCHR, using this as the smallest unit of practice and analysis. The 3 - 4 municipalities will be chosen to represent the socio-ecological diversity and complexity of the region, and will possess seed political capital in the form of willing and eager influential partners, in-line with Level #1 of our capacity-building frame (**Table 1**, **Figure 2**). Students and faculty will form mutually beneficial capacity building partnerships with the pilot towns, and the objectives of the enterprise will be: 1) to co-identify the gateway issue/sector in the context of climate change (e.g. WATSAN, food and agriculture, public health); 2) to mobilize and integrate existing knowledge and capacities, initiating an integrated assessment for the town; 3) strengthen existing social and technical capacities, identify key gaps, and work to fill them collaboratively; and 4) manifest a powerful learning experience for our students and a new research approach for our faculty.

Pivotally, we are also engaging with a new breed of socio-technical enterprise organization, Isla Urbana, which functions on a for-profit platform with the objective of developing, demonstrating, and deploying ICP-type solutions to the WATSAN crisis. Isla Urbana is currently deploying rainfall-harvesting systems

in pilot municipalities, funded by the Mexico City Government, and is actively pursuing other municipal-scale systems to treat and reuse wastewater. Indeed, the ICP framework highlights the necessity to create and deploy such entities, so that a business-minded sustainability culture dovetails with academic integrators.

## 5.2 Integrative Domains

With an ICP ethos (**Domain 1**)—the guiding philosophy and spirit—we are framing the MLCHR's climate resilience and sustainability challenges in terms of opportunities to co-create a socio-technical capacity building enterprise. This enterprise innovates assessment and planning processes and outcomes, and places education and information resources at the center of the enterprise, with the university partnership serving as facilitator, catalyst, and integrator. This perspective allows us to embrace multiple domains of integration (see **3.1**-**3.6**). The guiding concept is that this represents a new kind of integrative, collaborative development project/program, one that prioritizes human capital and social capital over manufactured technological capital and financial capital, viewing the latter two as enablers—but not drivers—of climate-resilient socio-ecological systems. Our objective is to learn from the application of ICP in several pilot municipalities of the region: a sampling that represents the diversity of social, cultural, political, economic, ecological and climate-change conditions (**5.1**).

Domain 2 (sectors, topics, issues) is helping us to contemplate multiple sectors, topics and issues, and their interconnectedness within the region. For example, we may use WATSAN as a gateway sector in one pilot town, food and agriculture in another, public health in another, infrastructure or urban design in a fourth. The interconnections among the pilot towns and sectors will comprise one lens for looking at the region as a whole, from local scale upwards. The other, larger complementary scale will be to look at regional scale information, data and indicators, and climate-change scenarios. This is also in-line with **Domain 3** (spatial and temporal scales).

Intuitively, anecdotally, and based on limited data, sectors like WATSAN, food and agriculture, energy, and public health do enjoy considerable interconnectedness—but how? We were unable to find any limited or comprehensive dynamic systems models of the MLCHR that reveals connections in terms of the stocks and flows of material and energy, people and information—let alone how climate change scenarios may impact them. We anticipate using a participatory approach to dynamic systems modeling to reveal interconnections at differing scales, similar to methods used by other authors ([80] [114] [115]—see Integrated Assessment below in **5.3**). Sectoral interconnectedness has major implications for designing systems to create regional resilience, while at the same time building resilience at the local, municipal scale. Indeed, an overarching research question is: How do we co-create resilient systems that can operate at both the re-

gional and local scales? Designers and engineers will need to create interconnectedness with some redundancies, such that regional-scale systems buffer shocks and do not allow them to proliferate. Local-scale WATSAN, energy, food and health systems will need their own resilience, coordinated and linked—but also separable—from the larger urban and regional systems.

**Domain 3** (spatial and temporal scales) signals strongly to us that we need to consider multiple socio-ecological spatial scales for climate-resilience and sustainable development work: existing political and governance scales; potential new governance scales that constructively challenge power relations; socio-cultural scales that leverage socio-cultural diversities; ecological scales pertaining to ecosystem integrity and agroecology; and hydrological scales relating to water resources. GIS and remote sensing will allow us to map these and overlap them for greater spatial awareness and insight. In terms of governance, from smallest to largest these are: municipalities of states of the region (e.g. rural municipalities of the State of Puebla); municipalities of the MCMA; larger urban municipalities (e.g. City of Puebla); the urban agglomeration that is the MCMA; the MLCHR geopolitical system as a whole; and how the region and its constituents relate to the federal system of Mexico, its federal entities and governance. Hydrologically speaking, we will consider the aquifer systems of the region (70% of water used in the MCMA is from local aquifers), watersheds serving each city (and any water-supply coupled watersheds also serving a city); and the contiguous watersheds of the MLCHR (Figure 4(b)).

We encompass as our landscape unit of analysis therefore the aforementioned five major urban areas—MCMA, Pachuca, Puebla, Cuernavaca-Cuautla, and Toluca (Figure 4(a))—zooming-in and -out as appropriate. Of all of the integrative domains, arguably this one most challenges conventional thinking and practices that tend to be city-focused. While there are considerable political challenges to be overcome, the ethos of ICP—pooling assets and capacities—is expected to be disruptive in a positive sense. Limited evidence suggests that regional socio-ecological interdependencies will increase over time [116] [117]. The MCMA depends on the transfer of water from Río Lerma and Río Cutzamala watersheds to the west, resources that also serve Toluca and its environs [12] [112]. Temporally, **Domain 3** also informs the need for us to be considering short-, medium- and long-term needs and priorities during conceptualization, assessment, planning, implementation and management, monitoring and beyond. Attending to pressing needs that can be met with existing capacities—yielding tangible outcomes of a nascent ICP process—will be an important strategy for sustaining our stakeholder collaboration and building trust, and is thus pivotal to the success of the effort going forward.

**Domain 4** (stakeholder interests, relationships and capacities) calls on us to identify diverse MLCHR stakeholders, their interests, concerns and capacities, and to use appropriate participatory tools to engage them in meaningful ways. We will be using social network analysis and preliminary stakeholder meetings

in our pilot municipalities to carry out our baseline assessment of this domain. Choosing the right partners for the pilot effort will be essential: core team partners need to represent a diversity of local stakeholder interests, but be open and willing to collaborate by pooling their knowledge and social capital. They will also need to be strongly motivated to understand and address climate resilience and sustainability challenges for the greater social good, as well as their own tangible benefit. Among the key stakeholders in a given setting, schools, colleges and universities will be identified, local government officials with ethical standing in the community, local businesses who employ local people, and civil society organizations. Consistent with best practices of participatory development, we will listen and learn what is already happening in these communities to locate opportunities for synergistic activities. Until more financial support is garnered beyond seed monies, these stakeholders will be engaged in ways meaningful to them that do not exert a burden without a tangible benefit. The limits of volunteer energy at the outset are well known to us, and it is our intention to co-develop an ICP process, milestones and outcomes that further local and regional climate resilience and sustainability. The pilot work will help leverage larger financial support to compensate our partners going forward. An ICP's horizontal, transparent approach holds promise for sustained multi-stakeholder engagement, and the growth over time of trust and shared ownership.

**Domain 5** (knowledge types, models and methods) allows us to be intentional about identifying and integrating diverse types of knowledge and ways of knowing, especially valuing indigenous knowledge and the lived experience of local people in each pilot setting. In-line with ICP, it will be this shared knowledge base—the knowledge core of Figure 2—that will incentivize cooperation. Each partner will contribute knowledge and capacity, and benefit significantly from their integration in terms of climate-change resilience, and the mitigation of adverse impacts. Operationally, this domain shows up in the form of integrated assessment (Figure 1, **5.3**): it builds our societal capacity to understand complex socio-ecological problems, and will inform our response during integrated planning.

Lastly, **Domain 6** (socio-technical capacities and networks) is informing our pilot efforts because it explicitly recognizes that there are several discrete but interrelated levels of socio-technical capacity to attend to as a partnership (Figure 3). The six levels contemplated in ICP work (Table 1) will be used, as in our earlier pilot work [10], in each pilot town as a template for gap analysis and strategic planning. We will use it with stakeholder partners to assess existing capacities and prioritize those that need to be strengthened. Notice how Domains 1 and 6 act as bookends for the ICP process, and how all six serve as an analytical framework for assessing existing resilience and sustainability projects (**3.7**), and for building resilience capacities for anticipated climate change impacts.

## 5.3. Operational Stages

As Table 3 shows, the ICP model is helpful when considering the various operational stages of a resilience project or program in each pilot setting. As indicated in 5.1, this begins with the Core Team at *Stage* 1: Imagination and ideas: imagining our project as a socio-technical capacity building enterprise, operating at municipal and regional scales in the MLCHR. The Core Team will consist of representatives of our three universities, plus carefully selected representatives of the major stakeholder groups—civil society, business, government and donors—who are receptive to an ICP ethos and enjoy regional influence.

Table 3. ICP operational stages, goals, questions, and descriptions (see Figure 1).

| Stage | Goal(s) | Key questions. Description. |
|---|---|---|
| 1. Imagination, ideas | Unleash creativity. | How is social capital and imagination fired? Use the power of collective imagination to expand what is possible within and across domains, and begin with unfettered thinking and ideas. |
| 2. Ethos, concept & process design | Set ethos, approach and framing. | What is the driving ethos? How does it inform concept and process? Conceive of and frame the effort as an ICP using Domain 1, with up-front attention to Domains 2 - 6. |
| 3. Integrated assessment | Identify needs, characterize baseline conditions to inform planning. | What are the baseline socio-ecological conditions? What are the needs of diverse groups? How have conditions changed (historical trends)? How are they projected to change under business-as-usual scenario? Use indicators for social, cultural, political, economic and ecological conditions (a subset of which will be used for impacts assessment, e.g. EIA in the planning stage). Includes: Characterize multiple sectors/issues (Domain 2); consider spatial scales (local and regional) and temporal scales (short, medium, long); characterize social groups and relationships (Domain 4); leverage knowledge types (5); inventory existing social and technical capacities (6). |
| 4. Integrated planning | Vision sustainable futures, compare project alternatives using impact criteria, choose most resilient, sustainable project. | What are desirable futures? What are alternative ways to respond to needs and priorities? How do alternatives compare in terms of positive and negative impacts? How do projected impacts vary across populations and landscapes? Consider multiple sectors/issues (2); consider spatial scales (local and regional) and temporal scales (short, medium, long); leverage social groups and relationships (Domain 4); leverage knowledge types (5); strengthen social and technical capacities (6) as integral to any resilience project/plan/program. |
| 5. Project design | Provide details on activities and outcomes, timelines. | What is the design of the preferred, most resilient project? Answers: What to do? Why? Where? When? How? With whom? With what capacities/resources? Use ICP model, with project activities, processes and outcomes informed by Domains 1 - 6. |
| 6. Implementation & management | Actualize project and manage it over time. | Actualization and management keep an eye on domains of integration, and improve what aspects of integration matter, improving ICP frame for a given setting. |
| 7. Impact monitoring & evaluation | Gauge project impacts, changing needs and conditions, for adaptive response. | What are the impacts of the project? How do they compare with assessment and planning impact projections? What are we learning that informs future projects, and related work? Connects strongly to stages 3 - 5. Uses a subset of assessment indicators to gauge impacts (changes) to those indicators. These data have the capacity to re-inform stages 1 - 5 in ongoing/future resilience work. |

Facilitated by a university representative, the Core Team unleashes creativity to imagine what might be possible—to vision a plausible resilient future for the town and region—holding political and financial constraints temporarily at bay. This involves the important "blue sky" visioning exercise that asks: What do we want our town and region to look like in 2030, 2050? Visioning can be assisted by the visual and performing arts, animation, simulation, and also virtual reality. As a contrast, we can also vision the kind of future we are likely to inhabit if the trajectory of development is not changed (*i.e.* the business-as-usual scenario). The former desirable vision can serve in counterpoint to the latter, and can help incentivize change. This is followed by Stage 2: Ethos, concept and process design. The Core Team contemplates a governing sustainability ethos, one that places social equity and justice, economic equity and vitality, and ecological health and integrity at the center, as well as other principles and ideas that the stakeholder core team articulates in a way that is meaningful to all partners. Importantly, this is not the adoption of pre-existing definitions of sustainability or climate resilience, rather it is a group exercise that uses established principles to articulate each pilot ICP's working definitions of resilience and sustainability, and each one's objectives. During process design, we co-design how other stakeholders are to be involved in each subsequent stage, drawing heavily on participatory development methods (**2.2**).

Stage 3 is Integrated Assessment, which sits at the heart of an ICP because it co-creates sufficient shared understanding of historical, existing, and projected conditions. To accomplish this requires the integration of diverse knowledge types (Domain 5, **2.5**) and the collection, analysis, processing and interpretation of a rich variety of archival and existing data and information: narrative; photographic and video; qualitative; quantitative; and geospatial. This major ICP activity involves collaboratively choosing a comprehensive set of indicators, aspects people care about, and/or perspectives for gauging past and present social, cultural, political, economic and ecological conditions. We will then use these data to describe, characterize and/or model the state of existing sectors (e.g. WATSAN, energy, food) and issues. For example, we are beginning to conceptualize the WATSAN systems of each major city and watershed in the region, as well as any ways that they are coupled by engineering infrastructure. We contemplate using Vensim modeling software (Ventana Systems, Harvard, Massachusetts, USA), and Stella Architect software (isee Systems, Lebanon, New Hampshire, USA) for this purpose, and teaching our students how to create participatory models using the Mexico City Region. We anticipate carrying out participatory modeling of sectors and issues in each pilot municipality; participatory modeling is emerging as a useful tool for building shared understanding [80]. To respond to our guiding research question—How do we co-create resilient systems that can operate at both the regional and local scales?—we will also be considering the impacts of published climate-change scenarios for the region, over the short-, medium- and long-term time horizons, and how these changes to climate may in turn impact

the sectors and issues we have modeled. Spatial analysis and digital mapping using GIS and remote sensing data is an essential tool for integrated assessment, and we will pay particular attention to differences, variabilities and disparities in indicators across populations and geographical areas. Baseline assessment would not be complete without an inventory of existing assets and capacities, the identification of gaps in them, and their prioritization for capacity building activity.

Directly informed by the previous stage, during the integrated planning stage, we contemplate using a reduced, manageable set of the same impact indicators for three complementary exercises: i) visioning desirable future scenarios (related to Stage 1 above); ii) modeling changes/impacts to those indicators under different development scenarios, and comparing them using impacts assessment; and iii) considering how the spatial distributions of positive and negative impacts vary across populations and landscapes under alternative planning scenarios (strongly inter-related to integrated assessment). Our ICP approach to planning for the pilot municipalities and the larger MLCHR will be heavily influenced by all of the aforementioned integrative domains (**3.1**-**3.6**): we will use a gateway sector in each municipality as our entry point, then draw connections among multiple sectors under climate change scenarios, and with other municipalities and the larger region. For example, what are ways to interconnect municipal-scale WATSAN systems regionally to increase the resilience of municipalities and neighboring cities?

We will work in concert with local stakeholders to identify urgent issues and impacts that need to be mitigated in the short-term, ones that require medium-term actions, and also the long-term strategic plan. For each of the time horizons, we are setting the stage for a specific project design. Importantly, ICPs contemplate not only policy analysis (environmental impact assessment, including benefit-cost analysis) to identify the preferred development action(s), but also the capacity building activities required to enable, support and sustain the actions and adapt to changing conditions and priorities over time. In thinking forward to the project design stage, we anticipate the design of an ICP for climate resilience in each pilot municipality, co-created with a full spectrum of stakeholder partners. Each ICP for climate resilience will answer the seven basic questions: What to do? Why? Where? When? How? With whom? With what capacities and resources? Once again, all six domains will be informing this design stage, and it will be important for the municipal-scale designs to be influenced by neighboring towns and cities, and for the regional scale design to pay close attention to how actions and activities at local and regional scales are related. Implementation and project management are also being anticipated in integrative collaborative ways, and while they may appear as traditional roll-out actions and activities—for example engineering construction and project management—they will have stemmed from all previous ICP stages and domains, emerging with much stronger co-ownership and significantly greater impacts eq-

uity—balanced, fair distribution of positive and negative impacts among stakeholders. Finally, we anticipate that the monitoring and evaluation stage of the pilot ICP in the MLCHR will consider the actual positive and negative impacts of the implemented project over time, how they compare with what was projected by assessment and planning stages, and how the actuarial data can be used to improve the implemented project performance going forward, and the impacts modeling and designs for future projects. In summary, adopting an ICP approach allows for each project stage to be reimagined in the context of all other stages.

## 5.4. ICP Network

Domain 6 (socio-technical capacities and networks) pays attention to the different levels of socio-technical capacity across multiple sectors, and the ability to scale-up and scale-down societal responses (Figure 3). In the context of the MLCHR, Figure 5 shows such a capacity building network, with flows of assets, information, knowledge and capacities among cities in the region. Universities in each of the five major neighboring cities will have a special role in the ICP approach. Linked together they are equipped to provide integrating architecture for the ICP network and technical support for all project stages, especially integrated assessment.
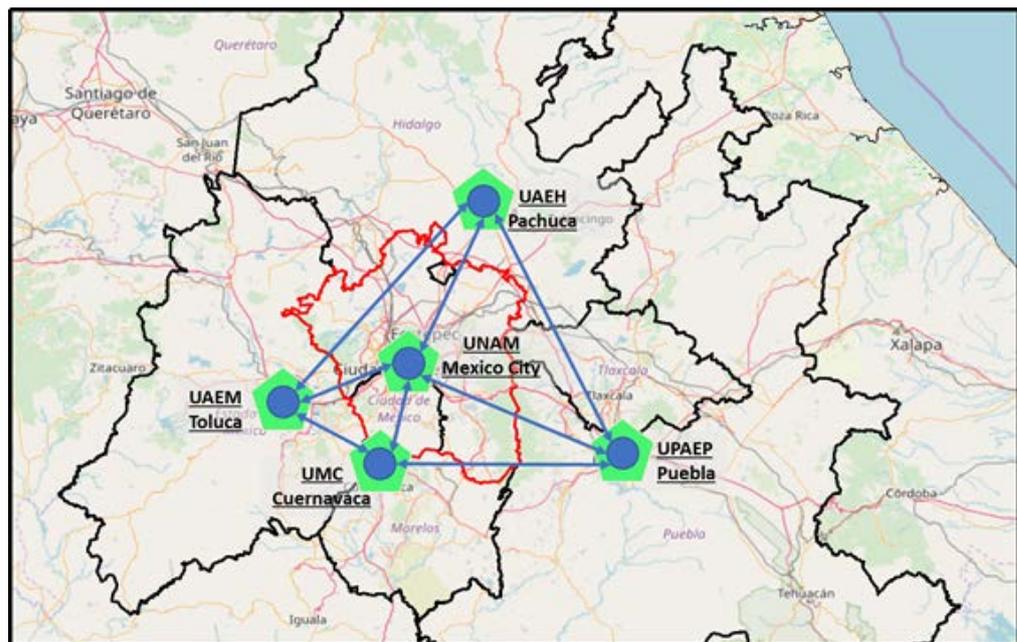


**Figure 5.** ICP network concept for MLCHR. Shows flows of information/knowledge, and exchanges/combinations of capacities among cities and sub-regions. The pentagons at each site reflect integration and flows across multiple sectors (Figure 2, Figure 3). The nodes of the network are universities: UNAM (Universidad Nacional Autónoma de México), Mexico City; UPAEP (Universidad Popular Autónoma del Estado de Puebla), Puebla; UMC (Universidad Morelos de Cuernavaca), Cuernavaca; UAEM (Universidad Autónoma del Estado de México), Toluca; UAEH (Universidad Autónoma del Estado de Hidalgo), Pachuca.

## 5.5. Power Dynamics, Institutions and Stakeholders

Based on empirical evidence (**2.1**), including our previous experience of ICP pilot work in three diverse cities of Mexico [10]—a highly stratified socio-political system (**4.0**), framing and actualizing sustainable development and climate resilience projects as socio-technical capacity building enterprises can be successful at mitigating obstructive and destructive power dynamics among stakeholder groups, including corruption. Eakin *et al.* ([118] p.1) emphasize the importance of understanding the "socio-political infrastructure" of the Mexico City context in the face of climate change impacts: "the social and political norms, values, rules, and relationships that undergird and structure the myriad decisions made by public and private actors". They recognize—as we do in the ICP approach—that this infrastructure and capacity is just as important as the engineering and "hard" infrastructure and environmental management capacity. The emphasis of the first five of the seven operational stages of the approach is first and foremost on building human and social capital (rather than manufactured and financial capital), and on constructively challenging business-as-usual practices, existing social hierarchies and power inequities. Local institutions, notably government agencies and universities, will have their interests served at the local scale by being active stakeholders in the core ICP teams of each pilot municipality. Likewise, other stakeholders. For example, our experience has shown that socially responsible, local, regional and national public agencies can escape the resource and knowledge constraints by becoming partners in a capacity-building enterprise. For example, knowledge integration, data analyses, GIS and remote sensing capacities, and modeling are all valuable capacities that benefit all stakeholders. Even politicians with narrow self-serving interests ignore social capital at their peril, and are apt to lend support to projects that solve pressing socio-ecological issues such as water scarcity, food insecurity or catastrophic flooding. Theoretically, there is a threshold politicians may perceive when failure to respond effectively to socio-ecological problems begins costing them too much political capital, while acting with intent to solve them—and following through with actions, for example as a good-faith ICP partner—gains them valuable capital [12].

With an ICP approach, universities are able to amplify their capacity to educate students and carry out research projects with positive socio-ecological impacts—also garnering a competitive advantage in the higher education arena. Understanding power dynamics in a given setting like the MLCHR is a prerequisite for finding ways to anticipate, navigate and mitigate political risks, while working to reduce them and amplify positive, constructive power dynamics. In our collective experience, an ICP-oriented alliance among the university sector, civil society groups who are often marginalized, socially and ecologically responsible government agencies, responsible businesses, and a pro-active, influential donor sector has substantial power and will enjoy a high probability of success in the face of complex socio-ecological problems.

## 6. Conclusion

Based on rich, empirical and experiential evidence, an integrative collaborative project (ICP) approach has the potential to inform important innovations to climate change resilience and urban/regional sustainable development projects and practices. It is flexible and adaptable to diverse, hyper-complex settings, as illustrated by the MLCHR context. The ICP approach frames efforts in terms of a socio-technical capacity building enterprise, with networks working at multiple scales, pooling knowledge and capacities among stakeholders. ICPs can act as powerful learning platforms in academic programs, and more widely at the societal level, reaching beyond trans-disciplinarity, engaged scholarship, and participatory methods. Universities are uniquely situated to act as facilitators, integrators and catalysts of this approach, by adopting people- and place-based teaching, learning, research and practice, in-line with an education-for-social-transformation paradigm. Likewise, a new breed of socio-technical enterprise organization with a strong business and sustainability culture is a necessary partner. In scenarios of the future, the socio-technical climate-change resilience and sustainability of dynamic socio-ecological systems will either increase or decrease over time. Amidst inherent uncertainties, one thing seems clear: if the business-as-usual scenario of development practice prevails, in an increasingly unstable climate-changing world, multifarious serious and inequitable negative impacts to people, settlements and ecosystems will occur, and compound each other. With an increasing number of agencies and scholars calling for integrative modes, and recognition of the inherently political nature of sustainable development, ICPs respond to conundrums and structural power dynamics to constructively challenge existing practice, crafting enduring, adaptive socio-technical collaborations among diverse stakeholders.

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## Author Contributions

Downs—ICP concept and pilot project operational view; Ruelle—resilience context and literature review; Brissett—education and role of universities; Hanumantha—maps, literature review; Krueger—empirical and theoretical bases; Mazari-Hiriart—MLCHR climate change context and pilot project view; Carr—critical development context, ICP bases.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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