Sustainability Living Lab for Food – Water – Energy in Urban Environments

December, 2022

Documentation of Stakeholder Workshops in Pune, India, July 2022

The FUSE project held its second set of workshops in Pune in July 2022. The goals of the workshops were to present FUSE policy-evaluation model results, ask for feedback, and to discuss additional potential policy interventions needed to reduce Food-Water-Energy (FWE) vulnerability and enhance sustainability. With this, the FUSE Sustainability Living Lab (SLL) approach in Pune has completed its final phase. In this document, we present the outcomes of these final workshops. We begin by summarizing the SLL approach, looking back at the initial February 2019 stakeholder workshops and subsequent development of the policy-evaluation model.

FUSE in a nutshell

FUSE (Food-water-energy for Urban Sustainable Environments) is a transdisciplinary research project (2018-2022) involving the Food-Water-Energy resources nexus in the Bhima basin, India, with a focus on the greater Pune metropolitan region. The project developed a long-term systems model that was used to identify viable paths to resource sustainability. We have brought together scientists, engineers, economists, urban sociologists and stakeholder engagement experts from Stanford University in California, USA, IIASA (International Institute for Applied Systems Analysis) in Laxenburg, Austria, UFZ (Helmholtz Centre for Environmental Research) in Leipzig, Germany, and ÖFSE (Austrian Foundation for Development Research) in Vienna, Austria. The project is a not-for-profit research effort and is part of the Sustainable Urbanisation Global Initiative of JPI Urban Europe and the Belmont Forum. Each of the national teams is supported individually by its own national science-funding agency. We have greatly benefitted from cooperation with the Gokhale Institute of Politics and Economics who as our partner organization provided workshop support, cooperated on our 1800-household survey and other focused surveys related to freshwater access and urban migration, and then led a student-run survey assessing the impacts of Covid-19 on food-water-energy resource provision in Pune.

More information: https://fuse.stanford.edu/

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Context:

Providing food, water, and energy (FWE) resources is crucial for human well-being. Population growth, rising consumption, and growing urban environments increase the demand for these resources. To analyze water security, a long-term integrated approach is needed that considers human decisions under different biophysical and economic constraints. This integrated approach can identify trade-offs and synergies between sustainability paths. The design and implementation of long-term strategies to achieve FWE-sustainability is a challenging task for all actors – including policy makers, civil society, the private sector and academia – who must consider a broad range of perspectives, ideas, and concerns.

The Pune metropolitan region in the Indian state of Maharashtra is growing rapidly. More than seven million people currently live in this urban region, and it is foreseeable that population will nearly double in the next few decades. Two elements characterize the region's stressed FWE system: a) intermittent freshwater and energy supply and b) competition between urban areas and agriculture for water and energy.

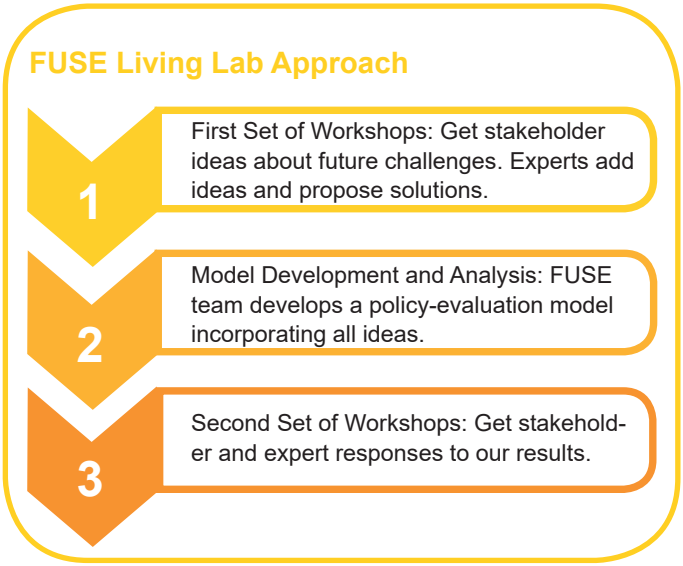
FUSE is a transdisciplinary research project that aims to identify solutions for long-term FWE sustainability in Pune (and surrounding Bhima basin) with a focus on water. Building on the knowledge of local stakeholders and experts, and data received from many sources, FUSE constructed a FWE systems model that captures connections and feedbacks among users, producers, distribution mechanisms, and resources. Our approach integrates narratives of future changes in climate, demographics, land use, and economic development, and considers the behavior of a wide range of actors. The model is used to evaluate policy interventions to identify implementable sustainability options based on a set of metrics of well-being.

Sustainability Living Lab Approach

To incorporate workshop participants' knowledge, expertise and views across Pune's society, FUSE adopted a Sustainability Living Lab (SLL) approach. The SLL approach includes a stakeholder analysis and two series of workshops, at the beginning and the end of the project period, respectively. In the first set of workshops (held in February 2019), stakeholders that are affected by FWE challenges and policy experts shared visions, challenges, coping strategies, and potential infrastructural and policy solutions under present and future conditions. Additionally, regional modelling experts contributed insights on nexus interlinkages of food, water, and energy.

The information gathered in the initial workshops and further local research activities was integrated into different parts of the research project. This information was used in part to formulate potential solutions, each requiring policy and infrastructural interventions. We evaluated these interventions under a range of future climate and population change scenarios. The likely benefits of these interventions were explored using our novel coupled human-natural systems model. We presented just a few major interventions that focused on the impact of prolonged future droughts, as this is a major looming concern.

In the second set of workshops (held in July 2022), these system model results were presented to representatives from NGOs, public authorities, and academia. Potential policy interventions were discussed, and feedback was elicited on the feasibility of, or barriers to, implementing interventions selected and modelled by the FUSE team. During the next two years, we will continue to develop the systems model and incorporate ideas expressed by our stakeholders for additional potential policy interventions and infrastructural improvements.



1 First set of workshops (February 2019)

The first set of workshops took place in February 2019 and was organized in cooperation with FUSE's local partner organization, the Gokhale Institute of Politics and Economics (**GIPE**). In total, the FUSE team and GIPE organized three workshops involving affected stakeholders (Stakeholder Workshop), policy experts (Expert Workshop), and modelers (Modelling Workshop).

In the **Stakeholder Workshop**, there were 30 participants from different FWE sectors. The goal was to collect FWE challenges, coping strategies, and ideas for solutions. Methodologically, participants first collected current FWE challenges. Subsequently, the FUSE team presented four different perspectives of potential future developments (relating to the potential increase in water scarcity, urbanization, energy demand, and transformation of agriculture). Participants jointly developed coping strategies and possible solutions to these future challenges.

In the **Expert Workshop**, there were 45 participants from the public and private sectors and academia. It aimed to define policy solutions to reach a shared vision for a sustainable Pune region by 2050. Methodologically, participants first designed the *future they want* in small groups. Based on the four perspectives presented by FUSE team members, as well as the results of the Stakeholder Workshop, participants discussed how to achieve the future they wish for – despite existing major challenges and the increasing stress on the FWE system. The solutions proposed in this workshop were used as the **basis for developing potential interventions** to be evaluated using the integrated system model.

In the **Modelling Workshop**, the FUSE team discussed the model structure with 12 modelling experts from academia and public institutions, listened to their feedback, and jointly co-created new ideas for model formulation.

Detailed documentation of the first set of workshops can be found here. It summarizes the key messages of the workshops, gives a more detailed presentation of the four different perspectives of potential future developments, and illustrates the solutions proposed by the participants to address challenges to FWE resource provision. The major challenges expressed during the 2019 workshops are summarized in a recent (2022) journal paper.

Further research activities in cooperation with local partners

The FUSE team maintained contact with many of our 87 stakeholders and continued to cooperate with local partners after the 2019 workshops.

In January 2020, FUSE held a workshop organized by ÖFSE in cooperation with the Centre for Environment Education (**CEE**) at which there were 40 participants. Presentations were given by the FUSE team and by Dr. Himanshu Kulkarni from **ACWADAM** (Advanced Center for Water Resources Development and Management).

In cooperation with Dr. Vishal Gaikwad from **GIPE**, Yuanzao Zhu (UFZ) conducted an in-depth survey in early 2020 of over 1800 households on their water and energy use in the Pune Metropolitan Region.

In cooperation with the NGO Maharashtra Social Housing and Action League (**MASHAL**), Heinrich Zozmann (UFZ) conducted interviews about water collection, storage and use with residents of four slum areas. Heinrich also conducted interviews in cooperation with the **Samidha Foundation** with tanker water business owners and truck drivers and implemented a monitoring study during which students from the **GIPE** counted water tankers at strategic observation points in Pune.

Raphael Karutz (UFZ) conducted semi-structured interviews with slum residents (**also in cooperation with MASHAL**) who had migrated to the city from rural areas. The aim was to deepen our understanding of migration trajectories, focusing on the relevance of food-water-energy challenges as drivers.

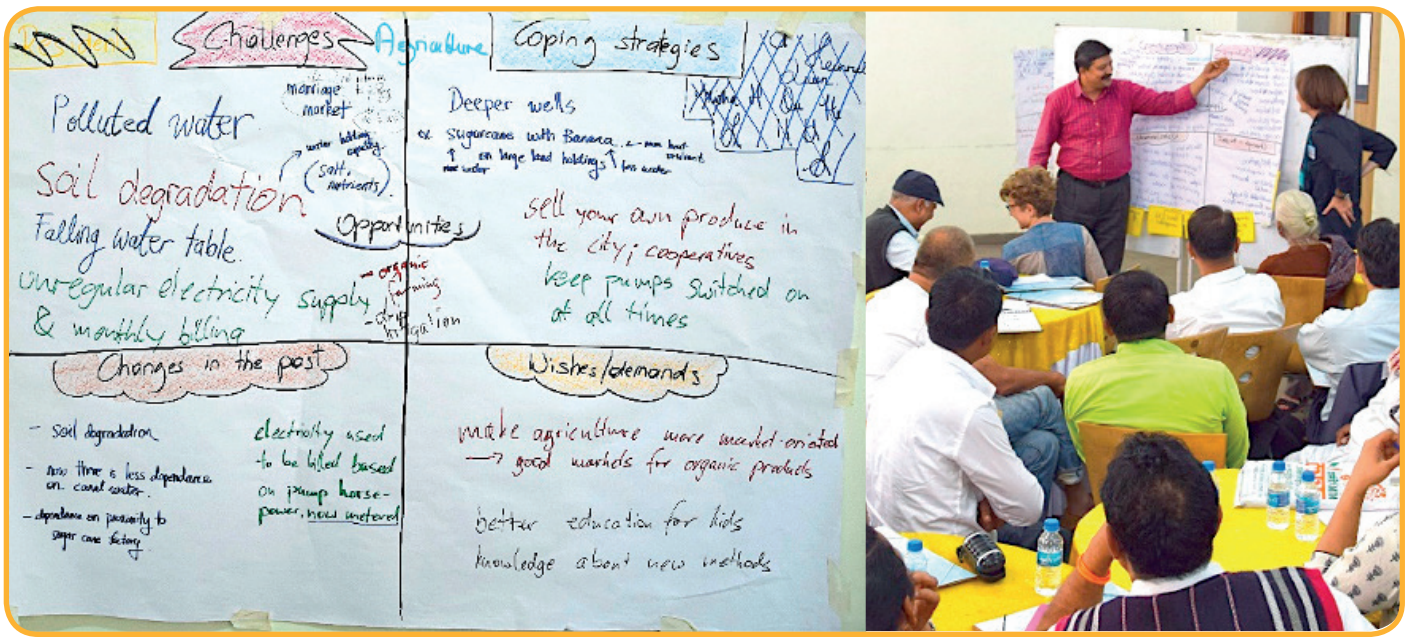
Steven Gorelick (Stanford University), Yuanzao Zhu (UFZ), Karin Küblböck and Hannes Grohs (ÖFSE) cooperated with Ashish Kulkarni and Saylee Jog from GIPE to organize a FUSE-internship for GIPE students. The students conducted the survey on the impact of Covid19 on the consumption of food, water, and energy resources in Pune city. The report can be found here.

Annual updates provided to stakeholders about project activities and our progress can be found by following the links for the two FUSE workshop documentation reports for 2020 and 2021.

The results of some of these research activities were presented at the workshops in July 2022 (see below).

2 Model Development & Analysis

2.1 Model Development based on Workshop Input



Challenges and Proposed Solutions

The workshops held in Pune in 2019 resulted in defining 22 distinct **challenges** that each affect one or more of the FWE dimensions or overarching system pressures. These challenges cover a range of concerns that include:

1. overarching exogenous and endogenous **<u>pressures</u> on the entire FWE nexus** system (e.g., climate change impacts, diminished fertile land),
2. **declining <u>state of the system</u>** (e.g., depletion of groundwater or the dominance of sugarcane cropping on water use), and
3. **<u>impacts</u> on society** (e.g., insufficient provision of water and energy).

These three challenges, along with consequent responses, fit into the Pressure-State-Impact-Response Framework widely used to assess the management of complex environmental problems. As Fig 1 shows, each of the identified 22 challenges falls into the pressure - system state - impacts construct. Furthermore, each challenge addresses at least one FWE nexus dimension indicated by the color of the boxes, blue = water, orange = energy, green = agriculture/food) and some address all of the challenges = grey. Most of these challenges are evaluated via policy **<u>responses</u>** that our integrated model was designed to address (outlined in blue), and others are ones that our model could not address (outlined in red) as they were beyond our scope.

Pressure Challenges: Maharashtra is one of the states in India most affected by climate change. Increasingly frequent and severe droughts and floods occur. The population of the basin grew from 8 million in 1975 to 20 million in 2020, mostly in urban areas. Maharashtra's per capita GDP (PPP) has increased more than six-fold since 1980. At the same time, overall economic inequality has risen. FWE resource consumption is directly linked to economic development: Between 1970-71 and 2018-19, electricity consumption in Maharashtra has increased 17-fold, and urban diets are based less and less on local agricultural production. Both agriculture and urban/industrial consumers rely on groundwater as well as surface water sources. Although the region is generally not water scarce, cumulative demand at times exceeds available freshwater supplies. Land cover and land use changes affect the availability of arable land in the basin: 80% of Pune's residential growth between 1985 and 2005 expanded to occupy land formerly used for agriculture.

System State Challenges: Particularly in the southern parts of the catchment area, periods of drought

have already led to crop failures in the past. Villages have sometimes had to abandon their farms and move to the city. In the city, water revenues from municipalities such as the Pune (PMC) are often insufficient to cover their operating and maintenance costs. The metering system has been completely abandoned in the residential sector, which in turn results in lost revenue and water-use inefficiency.

In rural areas, power supply interruptions are also frequent, especially agricultural electricity feeders that run pumps for groundwater irrigation. Due to the unreliability and low price of electricity, pumps are often run continuously, resulting in excessive extraction of groundwater. Fixed prices and the comparatively low demand for labor have led to a preference for sugarcane cultivation even in regions with low precipitation, resulting in disproportionately high surface water and groundwater abstraction. Approximately 20% of the total cultivated area is used for sugarcane cultivation. However, sugarcane requires about 80% of the total irrigation water, and as such is a major consumptive water user.

Urban informal use of water and energy was an important cross-cutting theme in all workshops, demonstrating how closely it is linked to many other challenges - and in some cases opportunities - involving the FWE nexus. There is a lack of regulation and enforcement of FWE resources in Pune. As noted by stakeholders, informality is present in the labor market, water sales through unregistered tankers, and the illegal sharing of electricity. In addition, the FWE nexus in Pune and indeed the Bhima basin is still largely regulated in silos, which hinders efficient and effective policy interventions.

Impact Challenges: People's access to freshwater includes temporal, spatial, logistical, and financial hurdles that consumers must overcome to obtain water. In Pune, piped water distribution is irregular and spatially uneven. Many newly developed areas on the outskirts of the city are beyond the reach of the current water supply network. Inadequate piped water supply forces people to adopt coping strategies such as using water storage or choosing alternative sources, which require consumers to take additional measures. Pune has been a regular victim of flooding over the years. Slum dwellers and rural migrants have been particularly hard hit. Stakeholders were convinced that these were consequences of both climate change, urbanization on the floodplain, and inadequate infrastructure.

Provision and access to energy and food also present impact challenges. For example, energy resources are a cost-element of water tanker truck transport. Energy prices have risen significantly over the past 10 years, especially for commercial and industrial consumers who cross-subsidize the nearly free electricity for the agricultural sector. Nutritious food is not affordable for everyone in Pune and the Bhima Basin. Changes in the agricultural sector are not only transforming regional food supplies, but they are also putting pressure on rural livelihoods, often culminating in migration to cities.

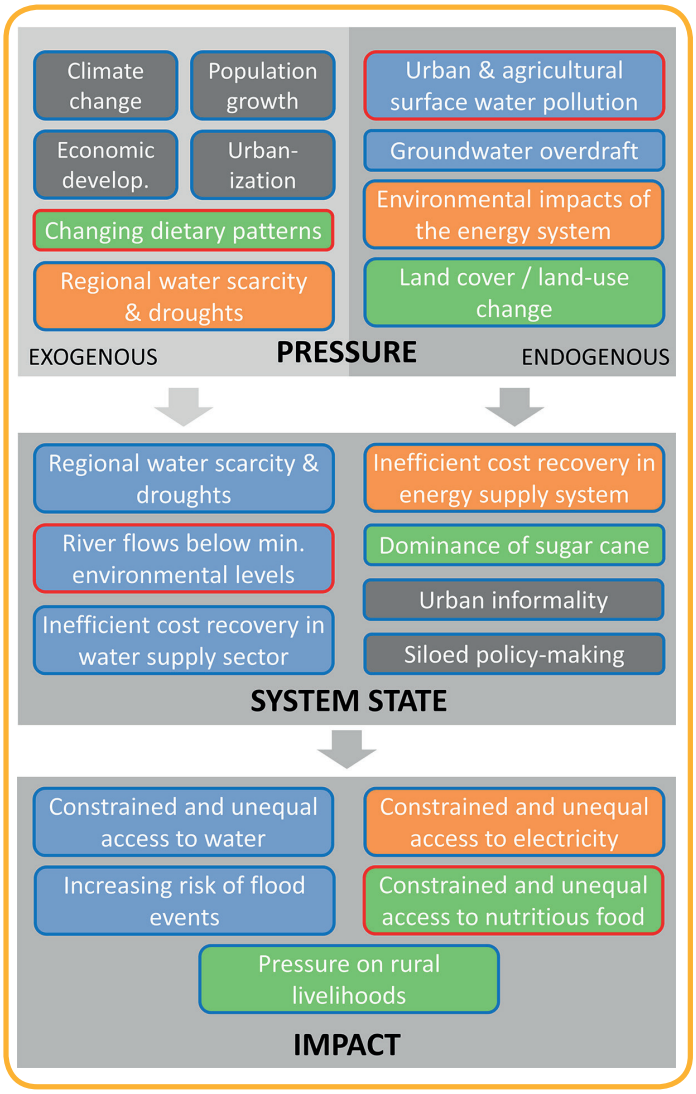


Figure 1: *Location of the 22 stakeholder challenges within the Pressure-State-Impact-Response (PSIR) framework, based on Karutz et al. (2022). The box fill color indicates the main FWE Nexus dimension of each challenge (blue=water, green=food, orange=energy, dark grey=multiple dimensions). The box frame color indicates whether or not the challenge could be accounted for in our integrated model analysis (blue = yes, red = no).*

Integrated urban Food-Water-Energy policy evaluation model

A major activity of the FUSE project team over the past four years has been the formulation and construction of a quantitative coupled human-natural systems model. The model is a modern simulation tool used to evaluate potential solutions to FWE challenges faced by Pune and also over the greater, mostly rural Bhima basin. This model simulates the environmental responses to future climate and land-use changes, and the simultaneous resource use and economic responses to changes in population, demography, and economics over space and time. The responses to the environmental conditions are captured in the model through **biophysical modules** involving hydrology, energy, and crop water use and yields. Decisions involving FWE resources use made by institutions (government and industry), consumers, and farmers are addressed in the model in **human modules**. In the model, energy resource provision and access are primarily for electricity to extract and transport groundwater (energy for water), but within the context of all energy use.

Fed into the integrated model is a set of **scenarios** representing influences that are not controlled by Pune region decision-makers (e.g., climate change, population growth, rate of economic development). The integrated model is then used as a quantitative tool to evaluate a variety of solutions that are aimed at overcoming the challenges. These solutions are referred to as policy **interventions**. The main idea is to identify interventions, which are likely to work and distinguish those that have little chance of providing any significant benefit.

Given the FWE system's inherent complexity, the model cannot be used to address every one of the 22 challenges in equal depth. Indeed, certain challenges, such as water quality degradation or issues of lifestyle changes, are beyond the scope of the model. All other challenges, however, are addressed one way or the other using the model. Generally, exogenous pressure challenges are considered in the model in the form of: 1) drivers (e.g., climate scenarios, socio-economic development trajectories), 2) endogenous pressure challenges in the form of endogenous model interlinkages, 3) state challenges based on the characteristics of model nexus components, and 4) physical impacts and human benefits by the quantification of a suite of well-being metrics. The resulting model structure is illustrated in **Figure 2**, highlighting endogenous (internal) linkages between modules, and **Figure 3**, showing exogenous (outside) as forces driving the processes simulated by the integrated model.

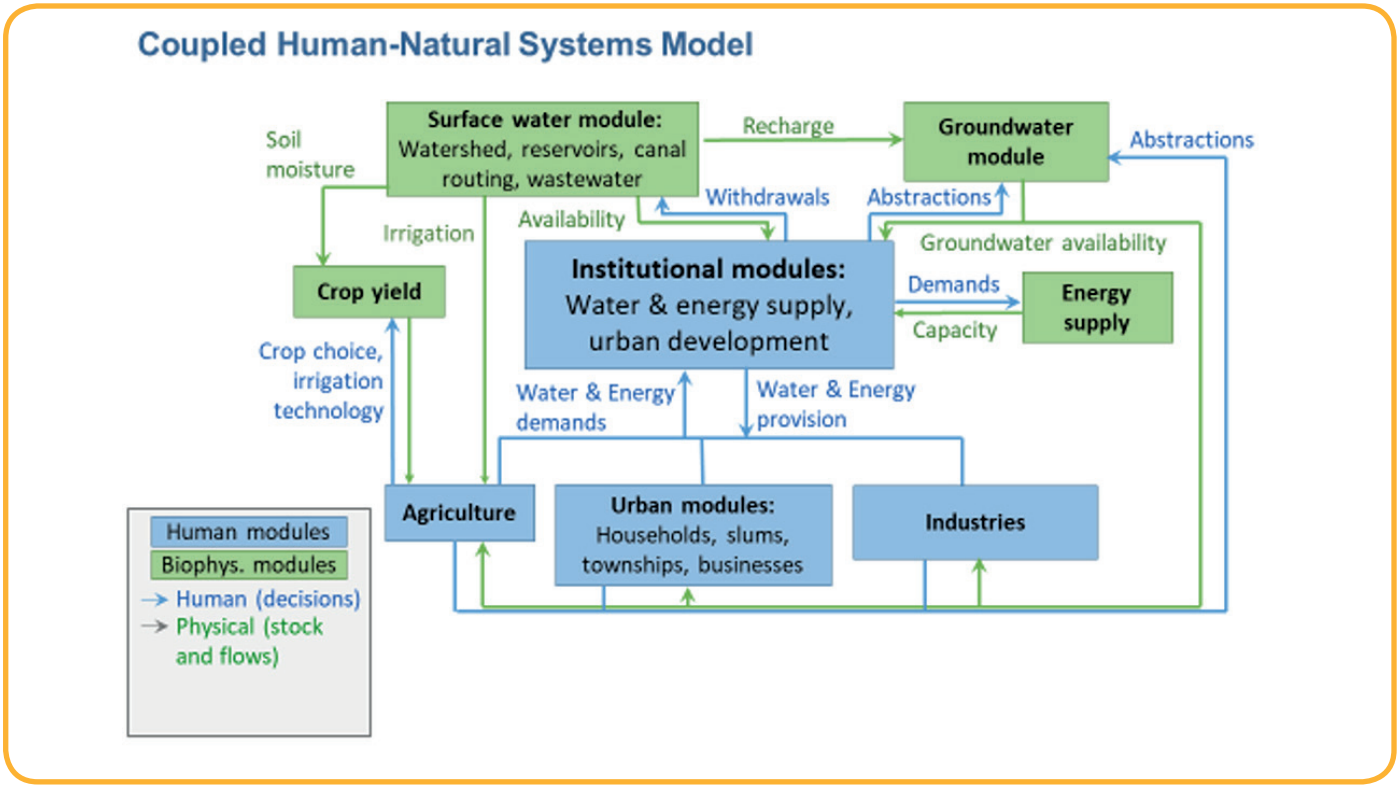


Figure 2: *Human and biophysical modules as well as internal linkages between them in the integrated model.*

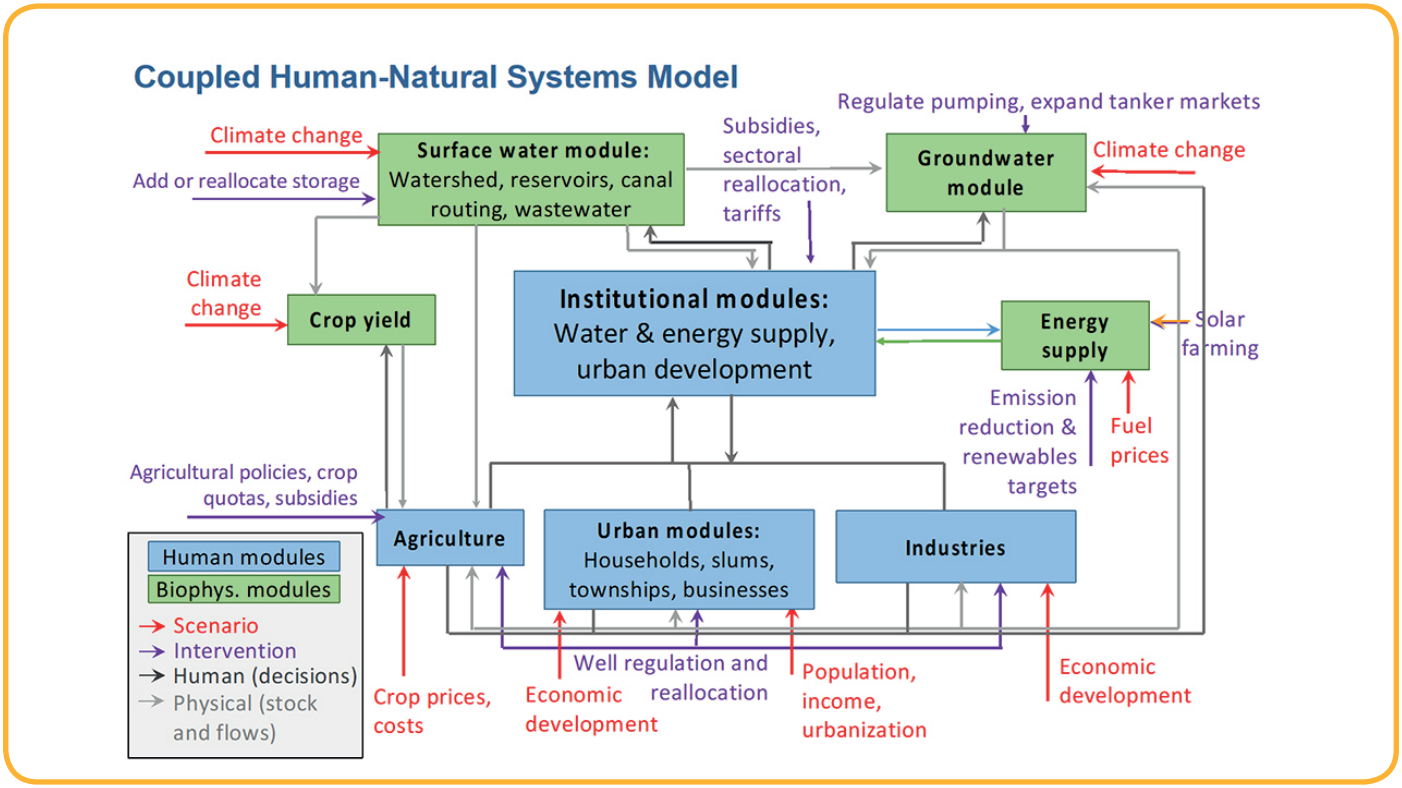


Figure 3: Scenarios and interventions that drive the integrated model.

Proposed Solutions: Response to Challenges

The FUSE team compared the baseline case "Business as Usual" to key interventions as potential responses that address specific nexus dimensions and their linkages. Of the 8 interventions shown below, we presented 4 at the workshops (1-4, see below). Currently, we are working on additional interventions (5-8, see below) that include one that is a Comprehensive Intervention and provides insight into the potential benefit obtained when different interventions are implemented simultaneously and interact:

0. **Business as usual: No introduction of new policy interventions** aimed at the FWE nexus.
1. **Expanded tanker water market capacity:** Supporting a larger fleet of tanker trucks to provide water supply from agricultural areas during urban water shortages.
2. **Urban groundwater demand management:** Conserving groundwater by incentivizing reduced urban groundwater abstractions or capping well pumping in the city.
3. **Agriculture to urban water supply:** Development of well fields around Pune city and buy-out of agricultural wells and pumping rights to increase urban water supply.
4. **Energy to urban water supply:** Reduction of water flows out of the Bhima basin for hydropower generation and use of this water quantity for urban supply within the basin.
5. **Limiting Urban Sprawl:** A regulation of urbanization to limit sprawl.
6. **Pune 24/7:** Continuous, efficient, and equitable water supply in urban areas.
7. **Solar Farming):** Decentralized agricultural solar power generation that can be fed into the electricity grid or used for irrigation pumping.
8. **Comprehensive Intervention:** Combining all of the above interventions.

At the 2022 workshops, we presented the **subset of 4 policy interventions targeted at coping with a multi-year drought under rapid population growth and urbanization**. These results were compared to the Business as Usual case (Figure 4). We identified this drought under rapid growth scenario-set as the most pressing FWE nexus future challenge to be addressed by our stakeholders and experts.

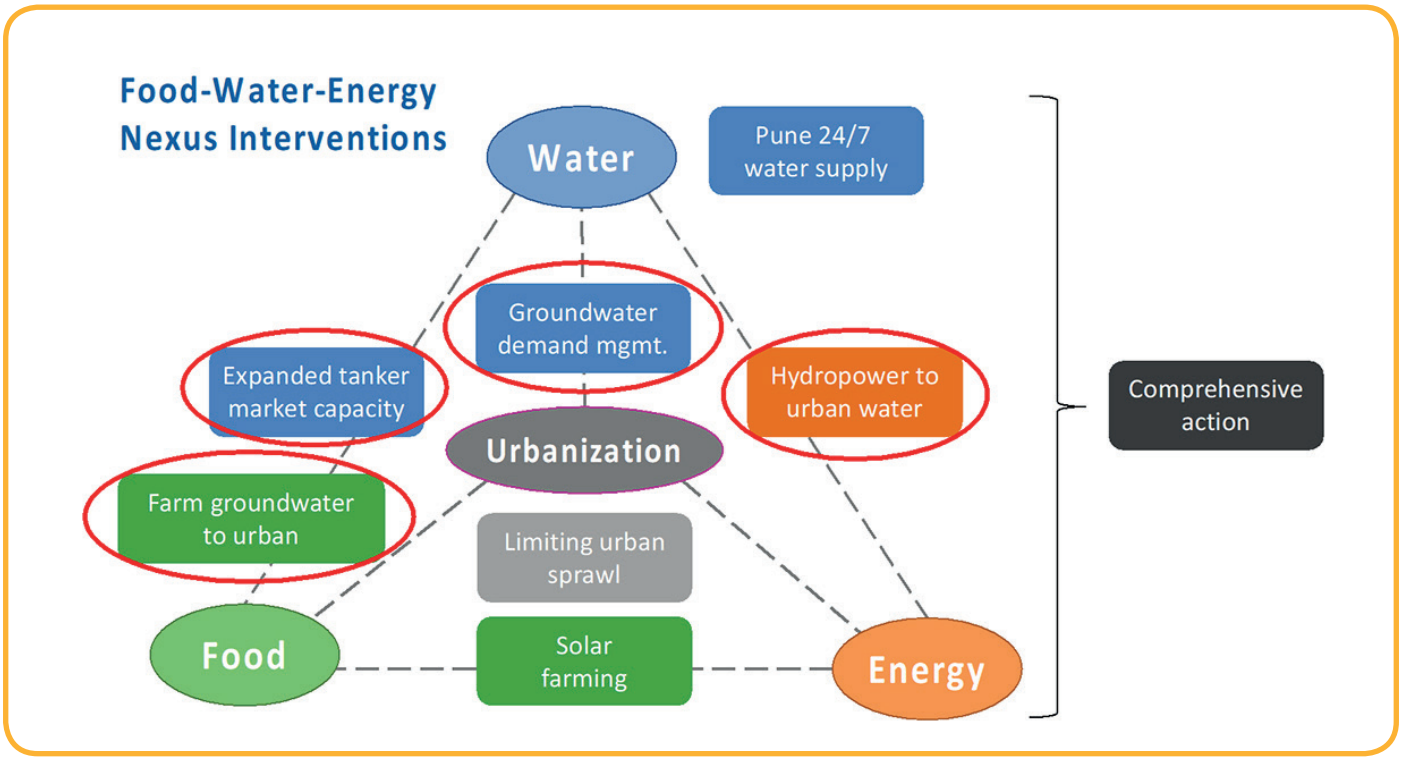


Figure 4: *The 8 interventions located in the FWE nexus. All are compared to the baseline Business as Usual case. The results based on those interventions circled in red are the 4 that were presented at the workshops.*

2.2 Model Analysis and Results

Narratives: Testing Interventions under Scenario Sets

To make meaningful statements about the effectiveness of proposed policy interventions, the FUSE team explored the four interventions that were then compared to the Business as Usual case under different future sets of scenarios. The scenario sets, described in detail below, involve two main **factors** that the Pune region cannot control. These represent "what if" future conditions. They involve either moderate or severe climate change, and either moderate or rapid population and economic growth. The different growth conditions consequently generate different patterns of migration from the city versus migration into the city.

The **first factor** is the **degree of uncertainty and severity of future climate change impacts** on temperature and precipitation. In **Figure 5**, we show the historical climate data compared to average of climate model projections for the periods 1990-2020 and 2025-2055, respectively. On average in the Pune region, temperatures stabilize at about 1C° above recent conditions by 2050 (**Figure 5a**) but with much greater climate extremes with 36% more hot (>38C°) days (**Figure 5b**). Generally, on average, the climate models suggest a slight (6.5%) increase in precipitation (**Figure 5c**), but larger flood events, and more intense and prolonged droughts (**Figure 5d**).

The **second factor accounts for changing socio-economic conditions**. These are represented by the **SSPs** (Shared Socio-economic Pathways), which are part of the IPCC report and specific to India. **SSP 1** represents rapid population and economic growth, and **SSP 3** represents modest population and economic growth (**Figure 6**). Projections were made to the early 2050s, when population is projected to grow from today's 7.4 million to 11.4 million in the Pune metro area. Maps showing how urban sprawl is projected to evolve to 2050 under SSP 3 appear in **Figure 7**.

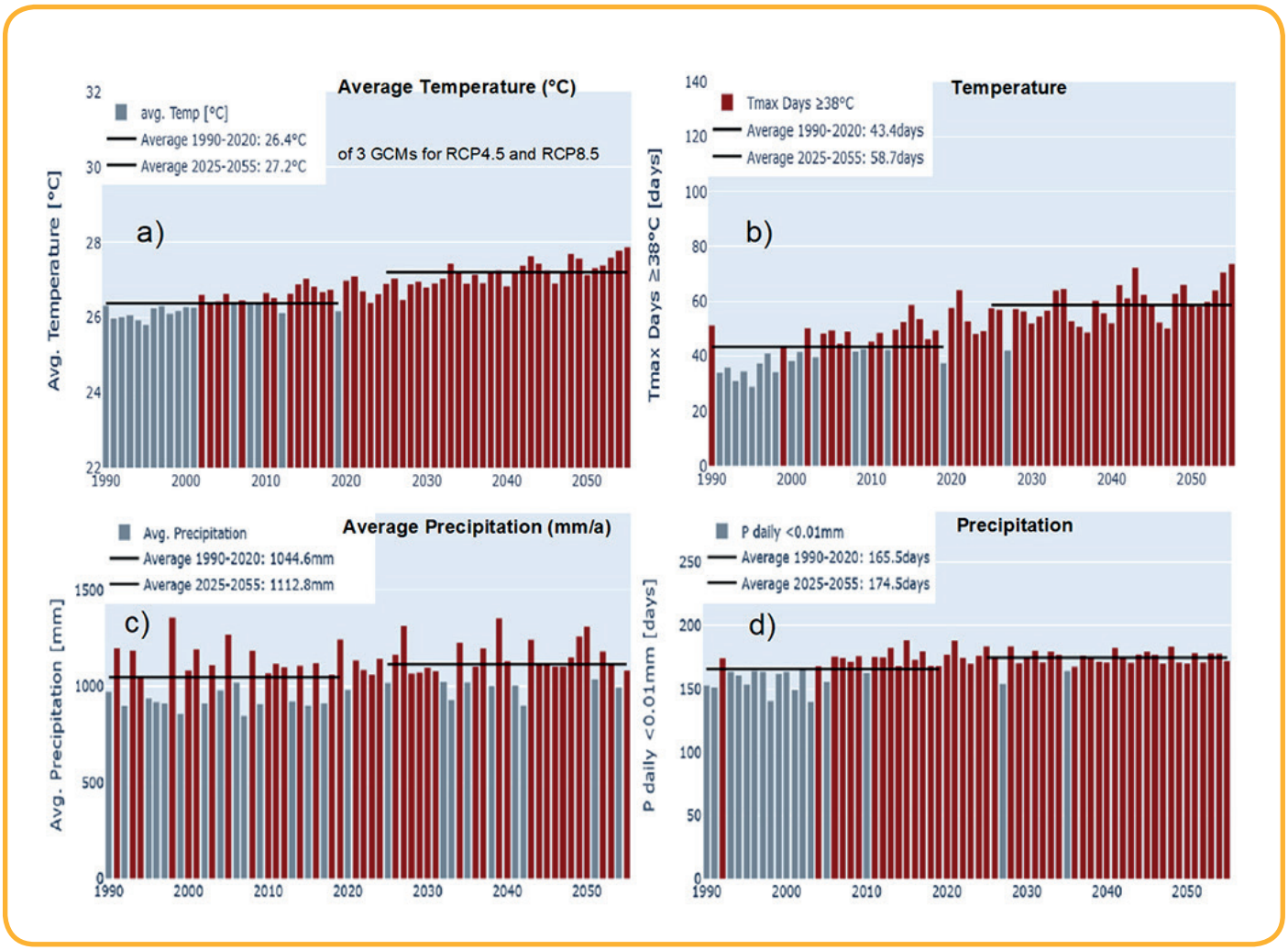


Figure 5: *a) Ensemble average temperature (°C), b) days above 38 °C, c) precipitation (mm/year) and d) days of no rain. All cases are an average of three General Circulation Models (GFDL-ESM2M, MIROC5, MPI_REMO2009) that include both RCP 4.5 and RCP 8.5 (moderate and extreme climate change, respectively) for the Bhima basin. The left black line is the historical average for 1990-2020 and the right black line is the projected average for 2025-2055.*

We created a web-tool on https://fuse-bhima-climate.herokuapp.com that illustrates climate change variability and uncertainty in the Bhima basin. This tool contains imbedded climate model results for three representative, bias-corrected General Circulation Models (GCMs) known as GFDL-ESM2M, MIROC5, MPI_REMO2009. These three models were selected from eight climate models that capture the range of projected climate change in the basin. The graphs in **Figure 5** show climate projections produced by the three GCMs under two climate change severity levels given by RCPs 4.5 (moderate) and RCP 8.5 (severe). As such, the graphs are each an average of six climate model simulations.

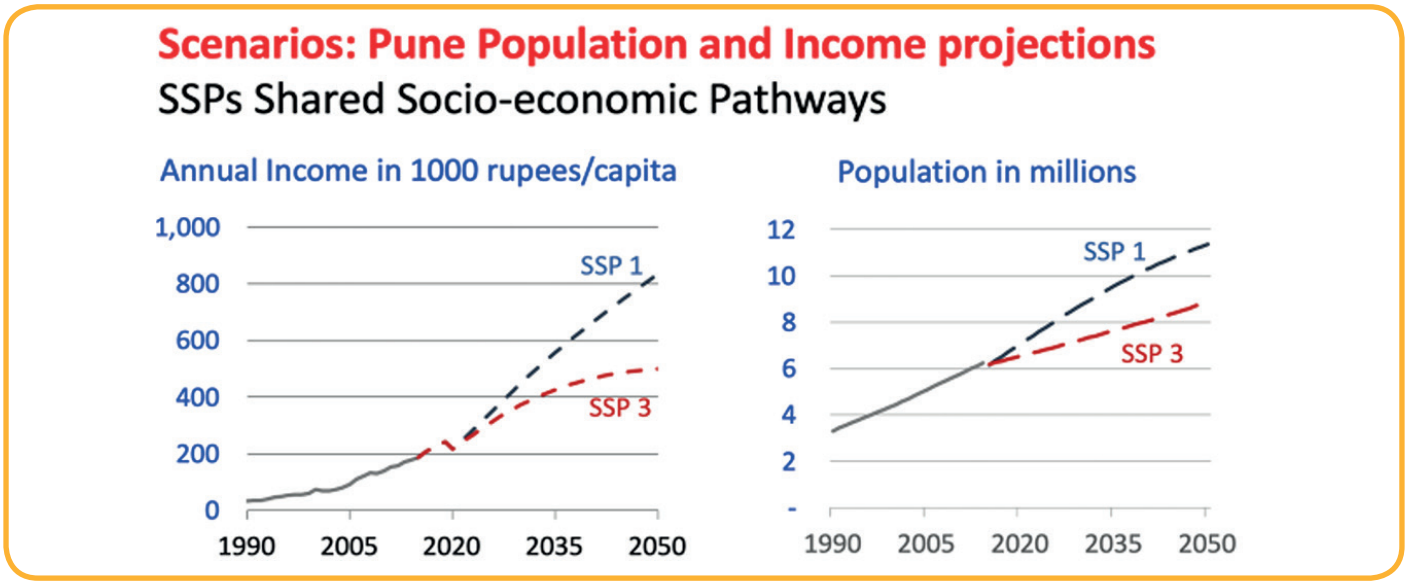


Figure 6: *Population and income projections based on downscaled Shared Socio-Economic Pathways (SSPs) 1 (fast growth) and 3 (slower growth).*

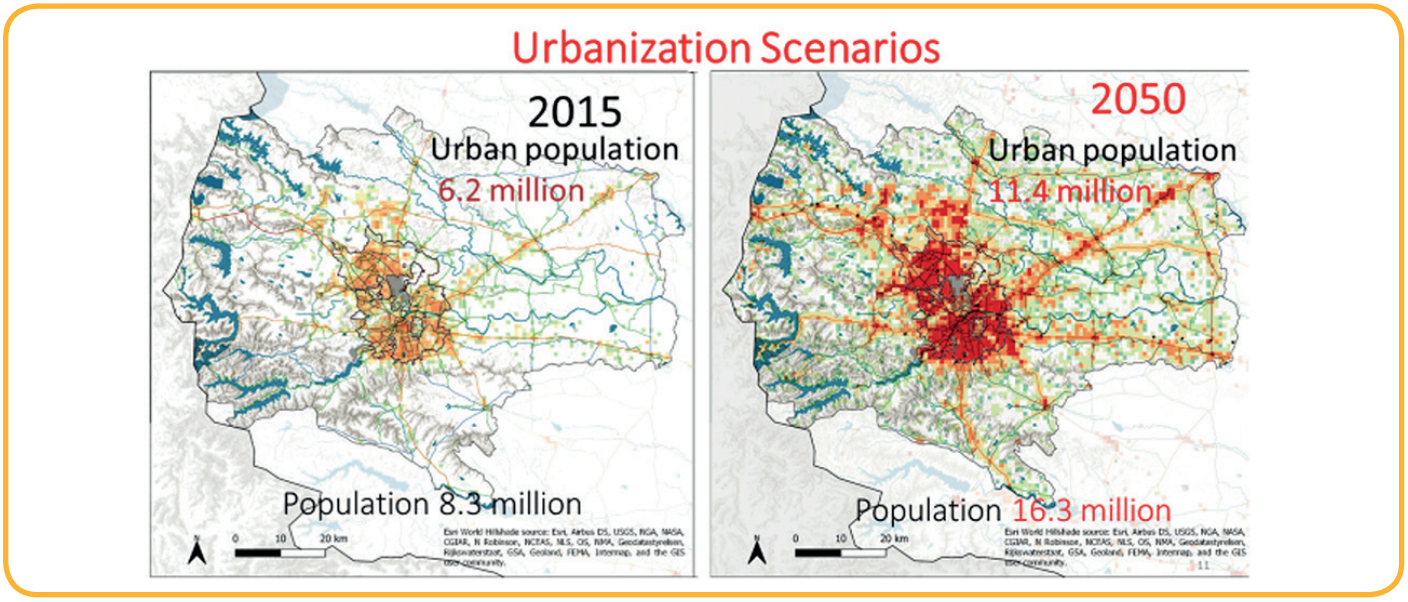


Figure 7: *Urban growth projection for Pune City and for the Pune Metropolitan Region under Shared Socio-Economic Pathway SSP 3.*

To gauge the benefits of each intervention we quantified changes in well-being using five metrics. These are vulnerability, stress duration, inequity, economic well-being, and physical impacts on reservoir and groundwater storage. These benefits focus on water and are summarized as:

- **Vulnerability** Percent of population receiving less than 40 liters/person/day of water
- **Stress Duration** Number of continuous months receiving less than 40 liters/capita/day
- **Inequity** Gini coefficient of water use (1 = supply disparity, 0 = equity)
- **Economic Impacts** Water costs (e.g., for pumping) incurred by various sectors as well a farmers profits
- **Physical Impacts** Spatial and temporal patterns of groundwater and reservoir depletion

The four selected interventions (**Figure 4**) under the scenario set (drought with rapid growth) were analyzed by comparing the impact of each intervention to the Business as Usual case. This analysis allowed us to see how the values of each metric evolves over time, providing insight into which interventions are most promising.

As illustrated below, **Figure 8** shows that given the challenges, the systems model serves as a tool that provides evaluations that inform decisions by policy makers and practitioners. In essence, the systems model takes scenarios and explores potential policy solutions by quantifying impacts using the well-being metrics. These are then compared to identify which solutions are likely to benefit society and which will not.

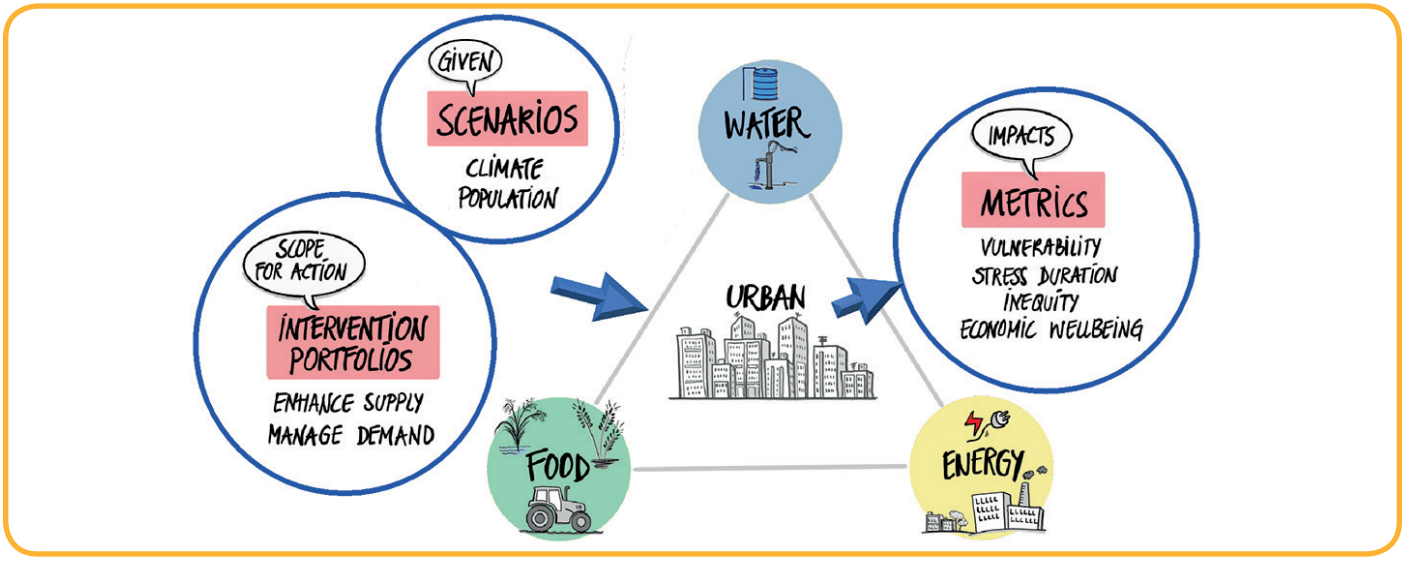


Figure 8: *Interplay of Scenarios, Interventions and Metrics of Well-being evaluated using the urban-FWE systems model. Visualization: Edith Steiner-Janesch brightpicture.at*

Results: Coping with multi-year droughts

We employed the systems model to analyze FWE sustainability under various scenarios and policy interventions through 2055 using the five well-being metrics (vulnerability, stress duration, inequity, economic impacts, and physical impacts). Population growth and socio-economic development follow SSP 1 - rapid growth in both. Our analyses revealed that particularly severe negative effects can be expected under a multi-year drought. Multi-year droughts are observed in climate projections and can cause reservoir depletion, water supply shortages, and steep trade-offs between the water demands of FWE sectors, such as household water provision, agricultural food production, and hydropower generation. The case of a particularly severe three-year drought (**Figure 9**) was found to lead to the full depletion of all freshwater reservoirs supplying Pune (**Figure 10**) and widespread groundwater depletion (**Figure 11**). We note that systems modeling results presented during the workshop were preliminary, and as such our final results may differ from those shown. However, we expect that the overall trends and conclusions will remain intact, and over the next two years we will continue to validate and improve the model.

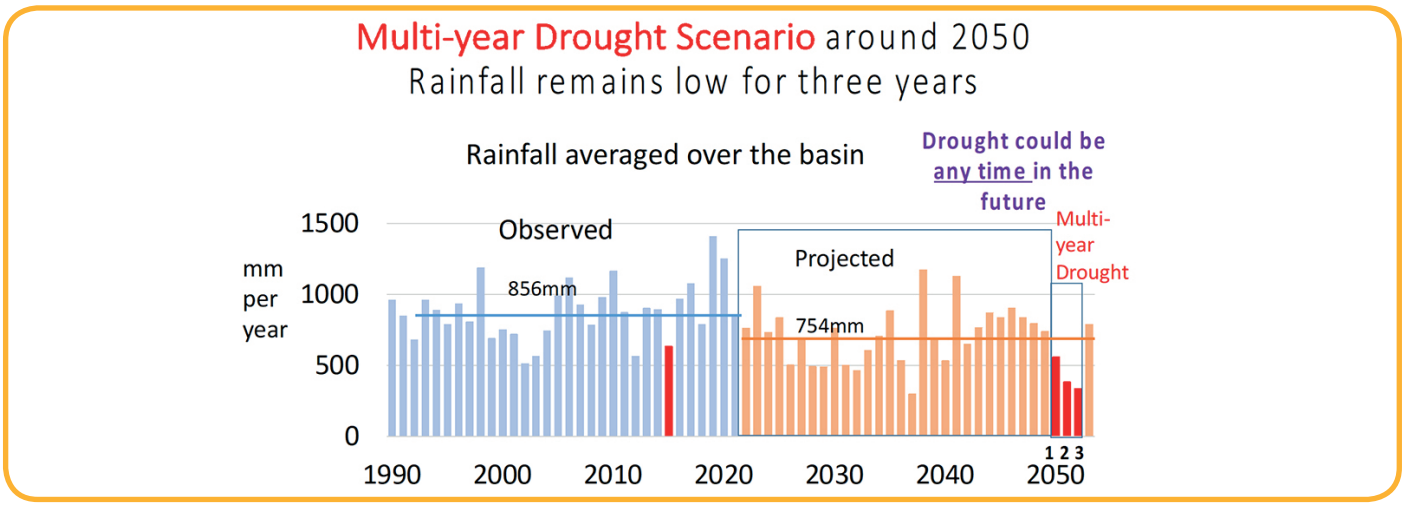


Figure 9: *Rainfall projection showing a multi-year drought scenario affecting Pune. A projected 3-year drought is seen around mid-century, but such a drought could occur at any time in the future. Such a drought period is not "predicted" at any particular time. We refer to the possible three-year drought (shown in red) by referring to year 1, 2, and 3.*

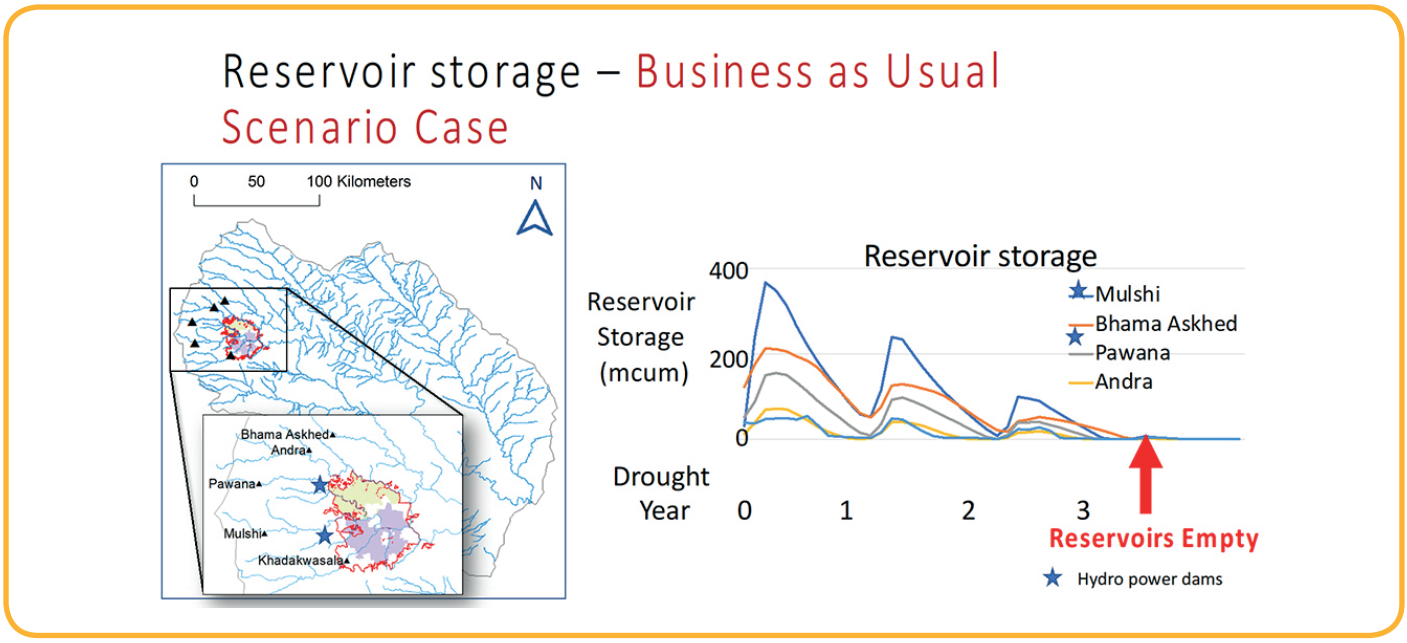


Figure 10: *Depletion of Pune's freshwater reservoirs given a future multi-year drought where year zero is a non-drought year.*

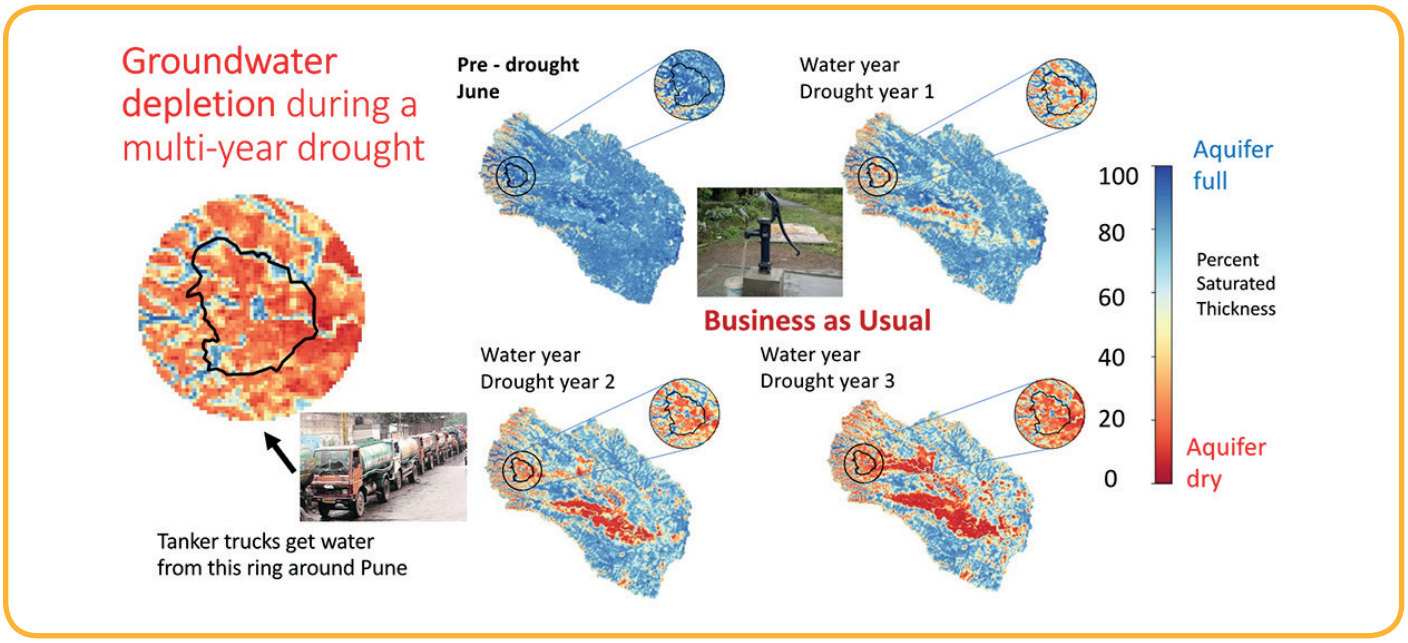


***Figure 11**: Depletion of Pune's groundwater resources under a multi-year drought. Tanker trucks provide water from a ring around the Pune metropolitan area.*

3 Second Set of Workshops

SLL2: 2nd Set of Workshops in Pune – July 2022

In July 2022, the FUSE team returned to Pune to present and discuss the analyses of its modelling results. Due to the Covid-19 pandemic, the workshops had to be delayed for almost two years, and progress was delayed, such that we presented our first set of results with findings in progress over the next two years.

Again made possible by the close collaboration with FUSE's local partner GIPE, two workshops were organized: A one-day Scientific Expert Workshop on July 18 was followed by a one-day Policy-Evaluation Expert Workshop on July 20. In addition, several side meetings took place with representatives from the Water Resources Department, the Pune Municipality, and various Non-Governmental Organizations.

Both workshops began with a short review of the SLLs in 2019, followed by a presentation of modelling results. The key messages conveyed were that Pune must become better prepared to deal with the impacts of climate change and population growth. There are combined impacts of increasing susceptibility to extensive multi-year droughts, greater flood events, and impending urbanization / population growth within the next 30-40 years. Dealing with future climate variability and urban density increases is a major challenge for which protective measures will take time to implement and planning must be started now.

Specifically, Pune needs to prepare by exploring preventive actions that address the region's more extreme weather events, and vulnerability affecting more and more people. At this workshop, we stressed that freshwater supply and access is a key driver that has notable effects on the agricultural and energy costs as both surface water and groundwater storage diminish significantly over a period of just two to three years.

Besides presenting those first modelling results and collecting feedback, the workshops engaged the stakeholders to identified further possible policy interventions, barriers that prevent their implementation, and measures to overcome those barriers. While the Scientific Workshop focused largely on presenting and discussing model results and additional elements of the FUSE research, the Policy Workshop focused on collecting and discussing potential policy interventions that could lead to beneficial reduction in short-term vulnerability and enhanced long-term sustainability of FWE resources.

Although the workshop activities centered on getting stakeholders' ideas about policy interventions and discussing their viability, several side meetings engaged local NGOs and government institutions to discuss further cooperation during the next two years as the project continues without Belmont Forum funding.

Scientific Workshop (July 18, 2022)

What: Present and discuss the results of modelling as well as of additional research conducted in the framework of the FUSE project; collect feedback on feasibility of policy interventions, and on further interventions.

Who: 40 participants from academia, public institutions, NGOs, and the private sector.

How: After a short review of the first set of workshops in 2019, the modelled interventions and their results were presented. Participants provided feedback on those results in small groups, addressing five guiding questions. After the lunch break, the FUSE team presented more detailed information about different parts of their research in eight "deep dive"-sessions. At the end of the workshop, participants shared ideas on further steps for dissemination and cooperation.

Step 1: Review of the SLLs in 2019 and introductory rounds

The workshop was opened with a warm welcome by Professor Ajit Ranade, Vice Chancellor of Gokhale Institute and an introductory round of the participants, many of whom had been present in the first workshops in 2019. Subsequently, Raphael Karutz (UFZ) and Karin Küblböck (ÖFSE) presented an overview of the 2019 workshops and explained how the FUSE team translated the results of these workshops into model properties, scenarios, and policy interventions. After this presentation, participants formed small groups which were then joined by FUSE team members. The groups had a short exchange on their particular interest in the workshop and on their potential thematic contribution.

Step 2: Model results and feedback

Project leader Steven Gorelick (Stanford) and economist Christian Klassert (UFZ) presented the concept of the integrated model and the projected range of socio-economic and climate scenarios Pune might face until the mid-2050s. The presentation focused on the effects of a multi-year drought under rapid growth as the biggest challenge to Pune's FWE nexus. The most critical effects pertained to household water access. These were evaluated using the water vulnerability metric measuring the percentage of the population with access to less than 40 liters per person per day of drinking water from any source (**Figure 12**). Under the multi-year drought, the vulnerable population was found to grow from 1 percent before the drought to 27 percent in year 1, 64 percent in year 2, and 80 percent in year 3. As seen in the figure, vulnerability is expected to first be most prevalent among low to middle income households, and gradually spread across all households over the course of the drought.

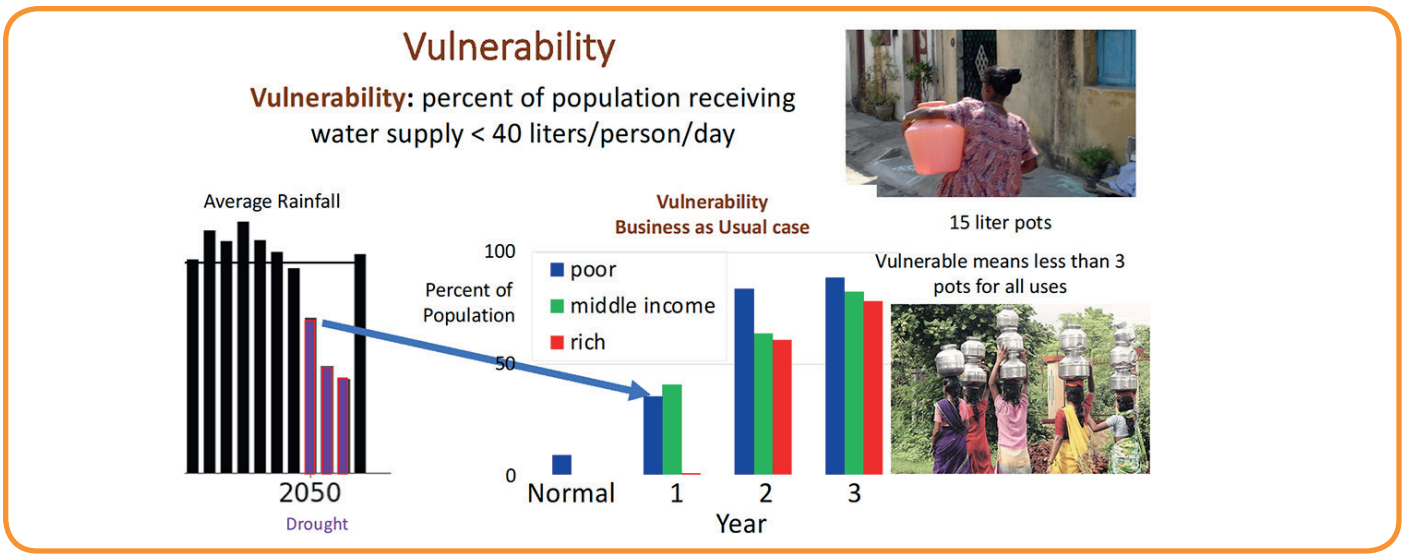


Figure 12: *FUSE model results showing vulnerability under a three-year drought in the Business as Usual case.*

The FUSE team tested a range of policy interventions based on solutions to enhance water security that were proposed during the 2019 workshop and other solution options discussed for Pune. The analyses found that none of the previously proposed solution options fully mitigate water vulnerability during a multi-year drought (**Figure 13**).

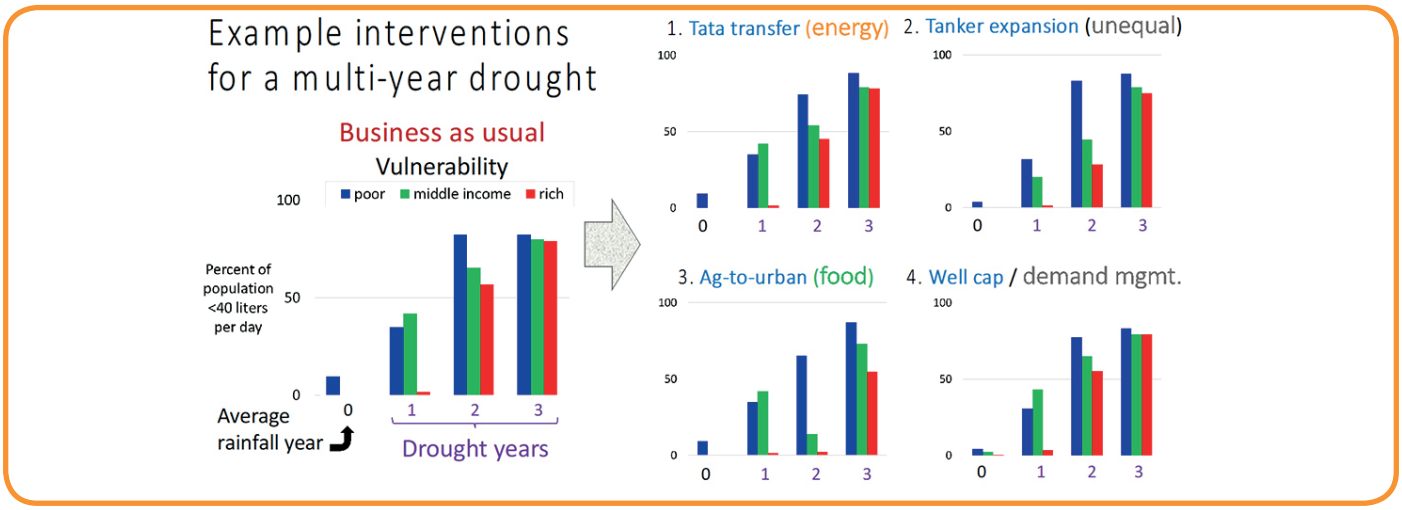


Figure 13: *Effects of policy interventions on water vulnerability during a multi-year drought.*

Figure 14 shows the vulnerability and the stress duration metrics results under the four example interventions, which are compared to future conditions under the Business as Usual future case. In all cases, the interventions in the first two years of the drought show some benefit to Pune's middle income and rich households, but only modest benefits to the urban poor. The water rental market intervention shows the most promise to mitigate drought. In this intervention, groundwater is purchased from farmers who forego some crop irrigation, and instead this water is then delivered to the city. However, it is important to note that like the other interventions there is minimal improvement in well-being of any economic class during the third year of the drought.

These results were used as a basis for discussion, to gain insight into which additional solutions the city might use to cope with such a severe drought and to test these solutions using the FUSE policy-evaluation model.

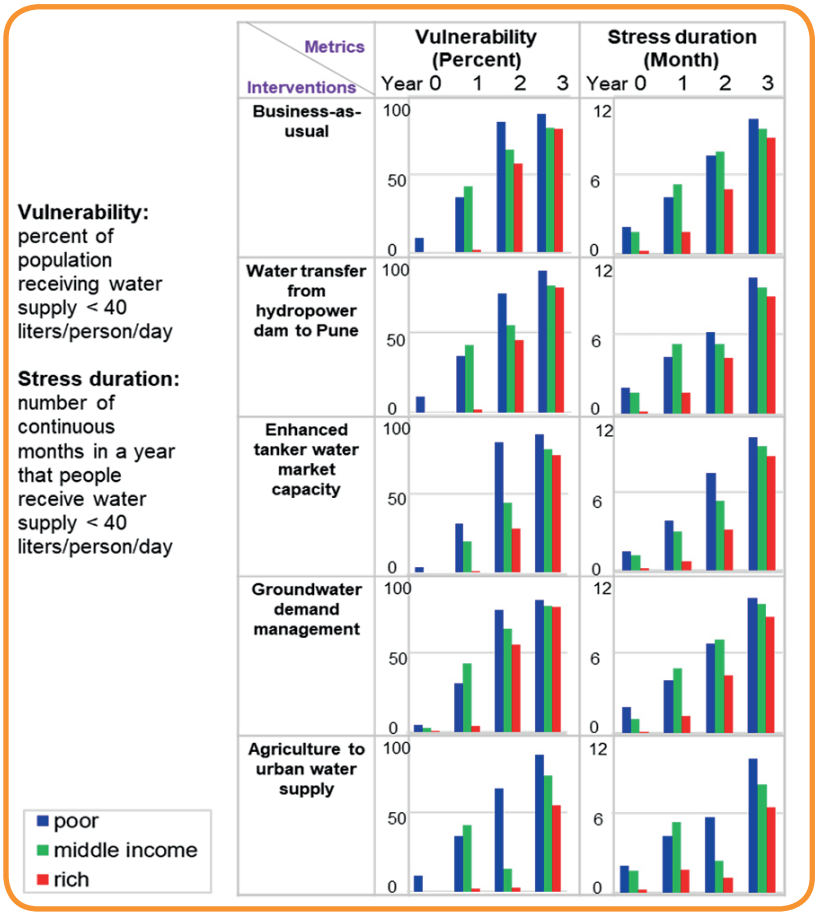


Figure 14: *Vulnerability and Stress Duration well-being metric values during year 0, which is a normal rainfall, non-drought period, followed by three consecutive years of drought. The results involving implementation of the four example interventions can be readily compared to the Business as Usual case over time.*

Feedback and Discussion by participants

After the presentation, participants provided feedback on the different interventions and their modelling results in small groups. Feedback was requested in response to five guiding questions: Does this confirm/contradict what you are expecting? What is new to you? What impacts are you most worried about? Which interventions are needed? What are barriers to implementation and how could they be overcome?

Generally speaking, participants were surprised by the FUSE-modelling outcome of the potential of a 3-year drought. Important issues that they brought up in the discussion were on one hand questions about the model itself, its assumptions and the data used. On the other hand, important questions revolved around water distribution between urban and rural areas, the lagging implementation of existing policies, the need to increase storage and grey water use, and require water supply metering.

The results of the discussion in detail:

Model assumptions and data

- Participants recognized that many important aspects are covered by the model. They underlined that the consideration of urban-rural interlinkages is crucial to capturing the dynamics of the complex system.
- However, a lot of questions were raised about the assumptions and the data used in the model. Participants confirmed that they have similar information on rainfall predictions – i.e., higher rainfall but for shorter periods in some years, and much less or no rainfall in other years. However, they were surprised to learn about the possibility of three subsequent drought years. The severity of climate extremes was questioned by several participants, arguing that the region is used to and prepared to deal with droughts and floods. However, there have been hundreds of deaths due to prior floods.

Storage of water

- Participants suggested that the Pune region should increase its efforts to store water e.g., in decentralized tanks, and via groundwater recharge in areas close to aquifers.
- They stated that a high percentage of sealed surface increases the risk of urban flooding and biodiversity reduction.
- Concern was voiced regarding the planned riverfront development in Pune and its effects on flood risk and river ecology.
- As a novel solution, the incentive of upstream afforestation (establishment of forests) was discussed, e.g., via payment for ecosystem service schemes.

Distribution of water

- Distributional issues between richer and poorer areas in Pune were discussed. Some participants stated that measures such as higher pricing of water for middle and upper classes should be applied. In this context the need to measure water use via meters was brought up.
- Participants proposed the introduction of water demand management, that accounts for population growth and migration to Pune urban areas.
- Another topic was the formal and informal use of tanker water. Participants stated that the tankers extract too much groundwater, and that tanker water is more expensive, threatening affordability for poorer households.
- Further, distribution between agricultural and urban water use was discussed. Participants questioned the FUSE model assumption that in dryer periods, agriculture should or would receive less water for irrigation while urban areas would continue to use high levels of freshwater, even though the current water allocation policy prioritizes urban water supply. They stressed the existing high pressure on rural livelihoods, leading to higher migration towards the urban areas.

Quality of water

- A topic that came up several times was the poor quality of water (which the FUSE model cannot take into account).
- Participants addressed the lack of water treatment plants which increases water pollution, especially downstream of Pune, and the degradation of soil quality.
- The need for the use of more grey water for irrigation and sanitation and the need for more efficient forms of irrigation were discussed in various groups.

Policies and their implementation

- Participants underlined that in Maharashtra and at a national level, many good policies and strategies regarding water exist, and that several projects are planned to improve the water situation in many places. However, often those policies and projects are not implemented.
- They also stressed the importance of increased cooperation between different sectors. They argued that existing institutions such as the Maharashtra Water Resources Regulatory Authority (MWRRA) should be strengthened.
- Participants recommended to the FUSE team to more closely look at existing policy documents and resolutions to get a better idea about planned interventions, and to use those to model comprehensive scenarios.

Step 3: Teaser presentations and "Deep Dives"

Before the lunch break, FUSE researchers Mikhail Smilovic and Peter Burek (IIASA), Yuanzao Zhu (also for Heinrich Zozmann) and Christian Klassert (UFZ), Ankun Wang and Irene Garousi-Nejad (Stanford University) presented their respective research results in short teaser presentations. After the lunch break, those research results were presented and discussed in a more detailed way ("deep dive sessions") in four streams, each consisting of two workshops. Heinrich Zozmann (UFZ) and Ju Young Lee (Stanford University) joined those sessions online. Participants could therefore attend two different deep dive sessions according to their main interests.

"Deep dive sessions"

Round	Stream 1	Stream 2	Stream 3	Stream 4
1	**Hydrologic & Climate Modelling I**	**Household FWE Vulnerability & Inequality**	**Urbanisation & Flood Risk**	**Future Nexus Scenarios – Interventions**
	Mikhail Smilovic, Peter Burek	Yuanzao Zhu, Heinrich Zozmann, Jasmin Heilemann	Raphael Karutz, Irene Garousi-Nejad	Steven Gorelick, Ankun Wang, Christian Klassert
2	**Hydrologic and Climate Modelling II**	**Household FWE Vulnerability & Interventions**	**Rural/Urban Migration & Inequality**	**Future Nexus Scenarios – How to deal with droughts & floods**
	Mikhail Smilovic, Peter Burek	Yuanzao Zhu, Heinrich Zozmann, Christian Klassert	Raphael Karutz, Ju Young Lee, Jasmin Heilemann	Steven Gorelick, Ankun Wang, Irene Garousi-Nejad
Notes	*Mansi Nagpal*	*Janhavi Angal*	*Ananya Mehrotra*	*Swagata Gedam*

Summary Deep Dive Sessions

Stream 1 hosted two sessions on **hydrologic and climate modelling**. In **round 1**, there was interest in model details of evapotranspiration; inclusion of an increasing number of wells in the scenarios; aquifers data used and validation results. For further improvements and greater reliability in model results, suggestions were made to look into detail and account for the effect of a rain shadow and local rainfall variability on climate and hydrology model projections for the Pune and Bhima basin. There was a proposal by stakeholders for an additional scenario of a shift in monsoon duration from JJAS to JASO/N. The participants were curious about drought vulnerability and measures taken for drought preparedness in other comparable basins. In **round 2**, hydrological simulations for various dams in the Bhima basin were discussed in detail to obtain expert feedback.

Stream 2 addressed **Household FWE vulnerability**. In the **first round** (Household FWE vulnerability & inequality) Yuanzao Zhu, Heinrich Zozmann and Jasmin Heilemann (all UFZ) presented results of a survey of almost two thousand households as well as of interviews with women living in slum areas. One result of the survey was that - due to intermittent water provision - households have to use electricity to pump water to water tanks located on the roof, which causes significant additional costs. In addition, if intermittent provision of electricity occurs, especially women have to spend considerable extra time getting water from external water pipes, causing significant opportunity costs. In the **second round**, Christian Klassert from UFZ joined the group to discuss possible interventions. Participants considered the research results useful for policy dialogue and were interested in methodologies and technical details of the survey and data used

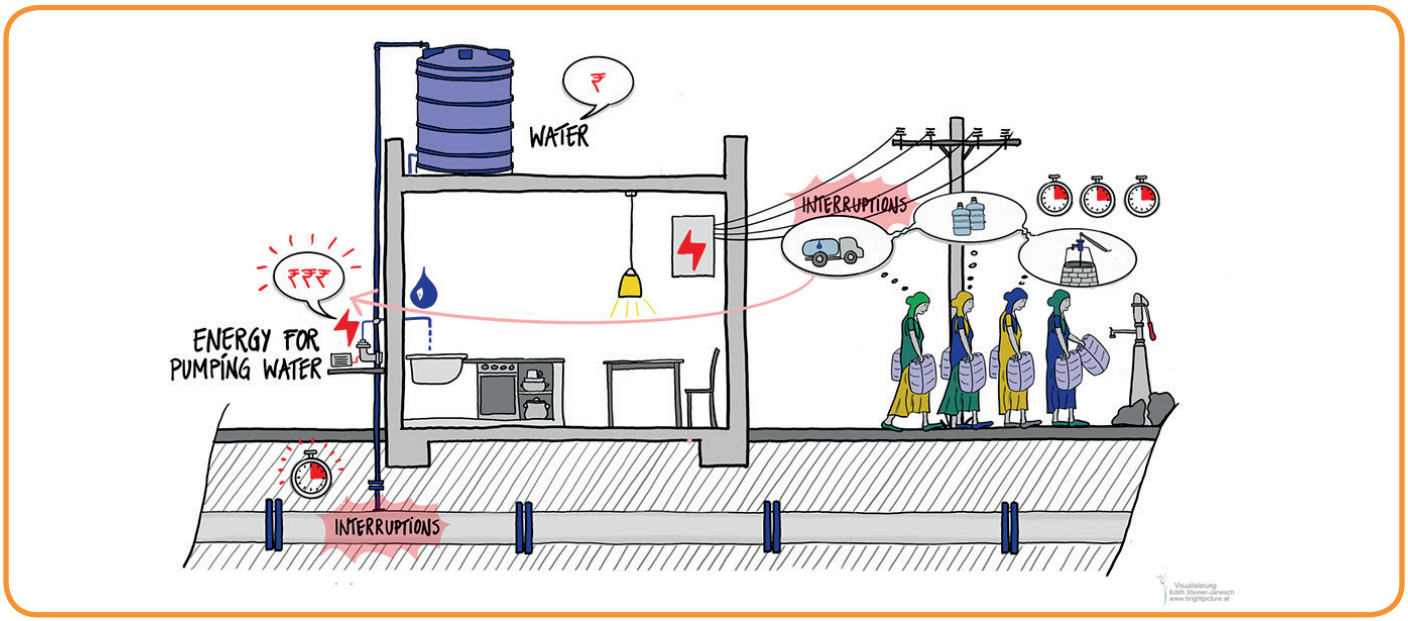


Figure 15: *intermittent provision of water and electricity cause significant opportunity costs, especially for women. Visualization: Edith Steiner-Janesch, brightpicture.at*

Stream 3 addressed in the **first part** the topic **Urbanization & Flood Risk**. Raphael Karutz (UFZ) and Irene Garousi-Nehad (Stanford University), presented research results on urbanization, rural-urban migration and flood risk in the city, respectively. The participants, mostly hydrology experts, agreed on the projected growth trajectories and highlighted the significant role that water availability - and livelihood opportunities related to it - plays in the migration decision of farmers. The discussion focused on the need to acknowledge the regional differences in carrying capacity and on the need to highlight the role of sugarcane as the major water consumer. The presented flood simulation approach was discussed in detail, also regarding existing models and data. Again, encroachment and currently planned riverfront developments were critically highlighted. In its **second part**, the group discussed rural/urban migration and inequality. Ju Young Lee (Stanford University), and Jasmin Heilemann and Raphael Karutz (UFZ) presented their work on sugarcane farming in the basin, inequality, and urbanization/rural-urban migration. The difficulty in accurate sugarcane cropping assessment was discussed. Modern irrigation methods and their potential to reduce water consumption are found to be less effective than assumed in literature. With regard to migration, the need to distinguish various migration groups (e.g., by socio-economic status, but also by caste) was noted.

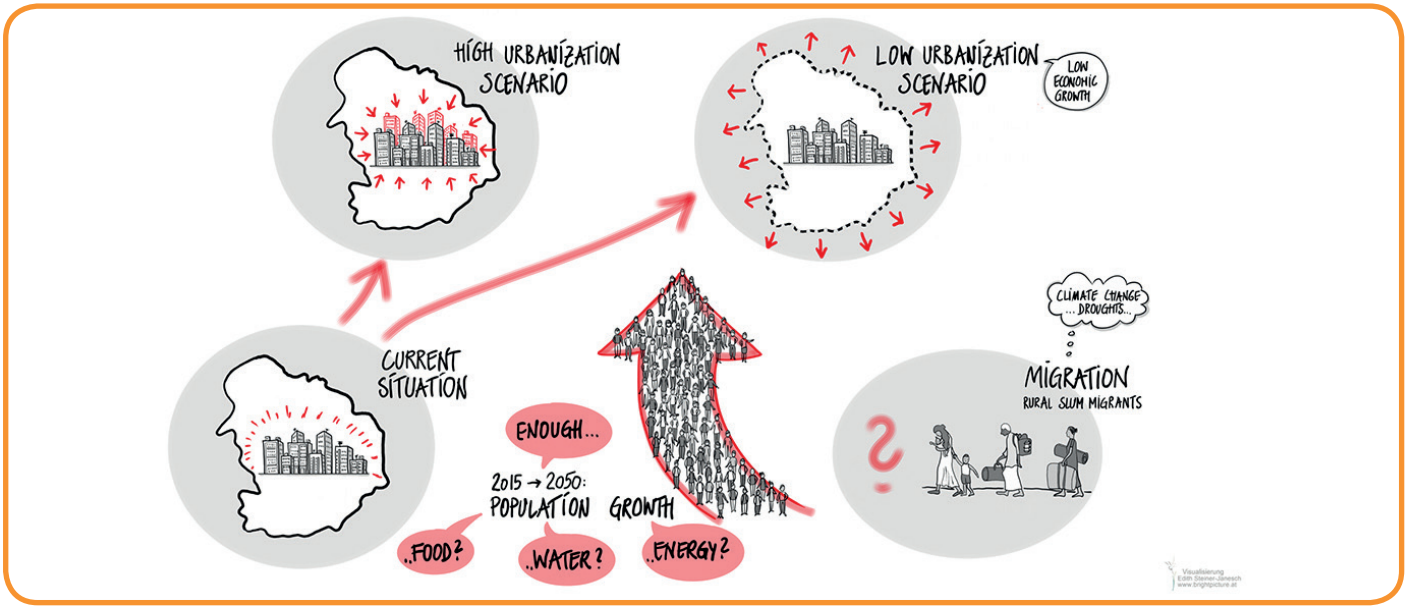


Figure 16: *Different urbanization scenarios have various implications for the FWE Nexus. Visualization Edith Steiner-Janesch, brightpicture.at*

Stream 4 focused on **Future Nexus Scenarios**. The **first round** started with a discussion of policy interventions to address multi-year droughts. The session was supported (virtually) by Ankun Wang (Stanford University) to answer questions related to her modelling efforts. Participants were particularly interested in data used to parameterize the household agents represented in the integrated model and assess their vulnerability. The data were obtained from a survey of 1800 households in Pune, plus a survey of over 100 households in informal settlements, which was conducted by the FUSE team in collaboration with the Gokhale Institute. The group discussed whether a move of agriculture away from sugarcane should be included as an additional scenario, though the superior profitability of sugarcane over all other crops makes this less likely. Participants further suggested considering the reduction of rural groundwater availability due to pesticide contamination and including livestock water use, although it only constitutes a minor share of total water use. The group also discussed that water saving via drip irrigation might not be economically viable in the Bhima basin.

In the **second round** the group discussed how to assess and deal with flood hazards. This included (re-) mapping of 25-year and 100-year floodplains, the risks of river-front development, and needed institutional planning and response.

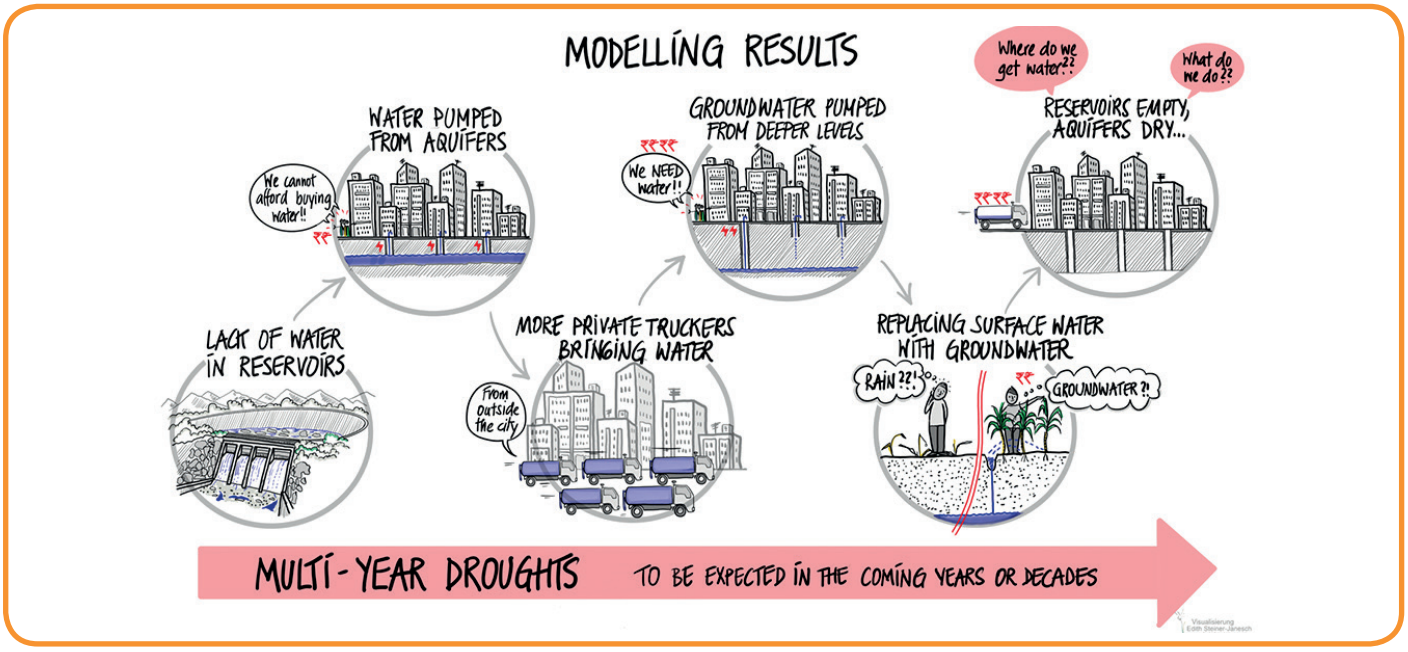


Figure 17*: What happens in case of multi-year droughts? Visualization: Edith Steiner-Janesch, brightpicture.at*

Step 4: Plenary discussion - How can the FUSE results be helpful and used further in Pune?

At the end of the deep dive session, participants discussed how the FUSE results could be helpful and used further in Pune. Participants suggested making FUSE results available to local authorities and the public to raise awareness of the current and future projections as a starting point. For instance, showing that the floods in 2005 and 2019 exceeded the 100-year flood and the possibility of a multi-year drought period in the future. In this regard, talking to the media, setting up free briefing calls, organizing press conferences and meetings, and presenting results and recommendations in environmental journals and feature articles were ideas participants outlined. The discussion also emphasized that recommendations based on FUSE results should go beyond the Bhima basin, highlighting the need for an integrated river basin management agency. For example, connections with the Namami Chandrabhaga program. Finally, participants suggested a collaboration between academic colleagues and the FUSE team to train engineers and researchers to use the developed model for further policy evaluations. This will allow the consideration of interventions such as shifting agricultural production to less water-intensive crops, preserving green areas, and providing greater riverfront development setbacks.

Policy Evaluation Workshop (July 20, 2022)

What: The purpose of the policy evaluation workshop was: 1) to inform participants about model results and receive feedback, and 2) to collect and discuss further policy interventions and to develop ideas on how to overcome implementation barriers.

Who: There were 30 participants from Non-Governmental Organizations (NGOs) in the areas of water, food, energy, urban matters, environmental protection, social issues, as well as representatives from public authorities and research institutes.

How: After briefly summarizing results of the first workshops in 2019, the FUSE team presented the model concept and model results for different baseline scenarios. As a next step, participants formed small groups and proposed potential policy interventions to deal with those scenarios. Those suggestions were presented and clustered. Subsequently, the FUSE team presented modelling results of selected interventions, which were then discussed in the plenary. After lunch, FUSE team members gave short presentations on further research findings. Participants then formed three groups and discussed different types of policy interventions as well as further possible dissemination activities of the FUSE project. During different periods of the workshop, experts from Pune contributed their thoughts and expertise in short presentations.

Step 1: Review of the Sustainability Living Labs (SLLs) in 2019 and introductory rounds

Similar to the Scientific Workshop, after a short introductory round, FUSE team members Raphael Karutz (UFZ) and Karin Küblböck (ÖFSE) gave a short overview of the 2019 workshops and explained how the results of these workshops were further processed. Subsequently, participants formed small groups of three, joined by FUSE team members, and had a short exchange about their interest in the workshop's content.

Step 2: Baseline scenario results, feedback and ideas for interventions

As a next step, Steven Gorelick presented the concept of the model and results for the baseline, business-as-usual scenario as described above, and Christian Klassert presented the four interventions and their results as modelled by FUSE.

Step 3: Presenting and discussing FUSE modelling results

After the presentations, participants asked questions and provided comments and feedback. Several questions addressed the parameters and assumptions of the model, such as the inclusion of spatial distribution or the change of life-style and land-use patterns. It was suggested to include the water footprint indicator, to look at the nutritional side of food security and to consider different degrees of vulnerability of drought and flood events in different parts of the population. Similar to the first workshop, participants pointed out that good governance needs policies and laws that are effectively implemented.

Subsequently, participants formed small groups and collected and discussed interventions that are needed to deal with the baseline scenarios presented. Each group proposed its three most important interventions.

Interventions considered key by participants were, amongst others, the increase of water storage, e.g., by increasing dam-storage capacity or increasing rainwater harvesting; improved demand management and efficiency, such as metering, water-reuse, improved governance and planning; increased capacity building, e.g., by educational measures, awareness raising and public participation. The interventions were clustered into different categories, forming the basis for the themes of the working groups in the afternoon.

Presentation by Professor Pradeep Purandare

Before the lunch break, Professor Pradeep Purandare, former director of the Water And Land Management Institute (WALMI) gave an overview of existing policies and strategies and underlined the need for their implementation. He stated that several policies were formulated in the past years in Maharashtra. However, the necessary legislation or the required governance structures were often not put in place to operationalize these strategies. Professor Purandare stressed the importance of looking at all existing strategies and plans and closely interacting with policy makers, field officers and Water User Associations

Step 4: Presenting further research results and thoughts

After the lunch break, FUSE members Peter Burek, Mikhail Smilovic, Raphael Karutz and Irene Garousi-Nejad each gave a short presentation of their respective research results. Their presentations got into significant detail and will be the subject of future FUSE project publications. When they are published, they will be accessible on the FUSE project website - fuse.stanford.edu.

Comment by K.J. Joy, SOPPECOM

After these presentations, K.J. Joy, founding member of the Society for Promoting Participative Ecosystem Management (SOPPECOM) provided his thoughts about conditions for research to have an impact, and on water conflicts.

He first stressed the need for reliable and accessible data and knowledge, and underlined that these two categories should not be confused with each other. In terms of data, he differentiated three sources of data that need to be combined and well-aligned: Long-term, macro data; Micro-data by local authorities; and crowd-sourced data. With regard to knowledge, he pointed out how uncertainty and variability increase when projecting the future. Often, averages are not useful anymore.

As a second theme he addressed related to water conflicts in the Bhima basin. He underlined that the Bhima basin has been and will be an area of water conflicts. Main axes of water conflicts are "conflicts of interest" between urban and rural sectors and between upstream and downstream areas. He underlined that these are unequal relationships as urban and upstream users have more power than rural/downstream users. He explained that demand management is too often discussed only for agriculture, while the industry is being left out of the discussion. He stated that water above lifeline use (25-40 l per person) should be met by recycled water.

Step 5: Discussing interventions, barriers, and measures to overcome them

After a lunch break, participants formed three Working Groups, two groups focused on the topics that had been identified in the morning session (increase storage and demand management, and reallocation of water), one group talked about Ideas for dissemination of FUSE results and further cooperation. Working group 1 and 2 followed a set of **guiding questions**: How do we evaluate this intervention? How could it be implemented? How can it be connected to existing policies? Who needs to be involved? What are barriers to implementation and how can they be overcome? What could be unintended consequences? How can they be dealt with? What would be the next steps? How could the FUSE project be useful in promoting the implementation?

Working Group 1: Drought Protection/Water Storage/Floods

Decentralized storage was viewed as critical for water security. Two modes of water storage interventions were discussed. One is underground storage tanks for individual households and larger storage tank facilities for apartment complexes. The other is surface water storage systems employing ponds (sometimes called "tanks") or lakes, which can be a short-term or perennial water sources.

Before digging into these alternative interventions, an effort was made to clarify what is meant by water storage. The first clarification was to specify the types of water storage involved: surface water, groundwater, soil moisture, short-term versus long-term, physical artificial holding tanks versus enhanced natural storage (e.g., ponds), and a general distinction between urban versus rural. For the purposes of FUSE interventions, we are interested in all forms of blue water storage (water in a form that it can be supplied to people or agriculture) for annual and interannual surface-water or groundwater storage, and not green water storage (soil moisture and not water contained in crops or plants). Hydrologically, soil moisture storage is handled directly by the agricultural module. Soil moisture is not a source of municipal or household water supply.

FUSE can simulate interventions involving conjunctive management of groundwater and surface water. For example, we can explore managed aquifer recharge through ponds and recharge wells. Although there was some enthusiasm for more buried water storage containers used by households, it was pointed out that the storage volume needed to provide many months of household supply likely would not be sufficient in Pune's monsoonal climate when there are many consecutive months with little rain, especially under projected future extended drought periods.

Six different problems and approaches were addressed by this group.

1. Water Storage Approaches

Rooftop Rainwater Harvesting: The group discussed the possible intervention of rooftop rainwater harvesting, which has been promoted in other regions of India. This intervention involves diverting rainwater from roofs to recharge wells or to small ponds. Such systems require ample subsurface space (deep water table) and geologic conditions such that water can be stored (high porosity) and retrieved (high hydraulic conductivity). This approach would be particularly valuable to capture and store water from high rainfall events. The PMC region provides tax rebates for construction of rainwater harvesting systems anywhere which was viewed as a flawed incentive. Water managers must ensure that rainwater harvesting is done in the right places where groundwater can be effectively stored and used.

Sponge City: The conversion of impervious to pervious areas would allow for greater groundwater recharge and storage, and it would also mitigate urban flooding. This approach has been applied elsewhere in the world, but it is unclear if it is feasible in the Pune metropolitan area, which is heavily paved and developed with urban residential, commercial, and industrial structures. It was suggested that emphasis should be on groundwater recharge as it is much simpler to achieve than storage systems. In rural areas, it was noted that for some farmland rainfall recharge has diminished. This is reportedly due to soil degradation stemming from excessive fertilizer use resulting in salt build-up and creation of a shallow "hardpan" layer that significantly reduces water infiltration.

Above-ground Storage: One suggestion was to use traditional bamboo grain storage containers that are common in agricultural areas. These structures can be lined with plastic and used to store water in rural areas, thereby providing low-cost, short-term, water storage. This approach would reduce the need to carry water from dug wells or streams, a job done almost exclusively by women.

2. Water Supply Via Tanker Truck Delivery:

Tanker trucks are already used to spatially reallocate groundwater by pumping from various areas and delivering this water to other areas. Problems with the current tanker market were raised. These comments focused on Pune's tanker water market being politically controlled, providing high quality drinking water primarily to rich households who can afford it. In addition, tankers obtain water from naturally occurring streams and small rivers or from groundwater adjacent to such rivers, thereby reducing baseflow. Consequently, there has been less flow in these water bodies. It was noted that in the urban context, "political circles" of tankers can dominate water provisioning, and in the rural context there are conflicts involving villagers not giving up their land for the construction of storage ponds that require significant space. Another reported tanker truck water issue in Pune is that the water is pumped from boreholes near contaminated streams. This water can be contaminated by pathogens and yet it is sold in areas where people may not be aware of the water quality supplied to them.

3. Public Wellfield Development

It was suggested that groundwater well fields in the Bhima basin outside of the metropolitan region could be developed to take advantage of stored and naturally replenished groundwater that could be delivered to the city. Such areas have yet to be identified. A piped network would have to be installed to deliver this water to Pune.

4. Agricultural Solutions

Reduction in consumptive water use was discussed as an alternative - using less water rather than storing more water. More water efficient selection of crops in the region could reduce water use and reduce soil quality degradation. There are historical incentives to grow sugarcane (Lee et al., 2019) and this includes farmers growing sugarcane due to a shortage of labor, as this crop is less labor intensive than others (particularly crops grown using organic farming).

Farmers should be incentivized to shift to more water-efficient cropping methods and to select crops based on water use. The impediments mentioned were: 1) Minimum support price for sugar versus other crops. 2) Selling of land is an attractive alternative for farmers in peri-urban areas owing to rapid urbanization. 3) People prefer working in factories as this is more secure compared to working on farms, which is seasonal.

5. Basin-wide Planning

Discussion also focused on a basin-wide strategy. There was a perceived need for a common body, an *integrated river basin management agency* as part of the state government that could connect the fragmented agencies that exist. In addition to providing 24/7 piped water supply, all reservoirs administered by PMRDA (Pune Metropolitan Region Development Authority) should be managed simultaneously. Water metering should be implemented, and a further regional aim should include women spending less time acquiring water. There was a sense that 24/7 piped water supply was not the most important goal for Pune because most urban water users already have 24/7 access to water as long as they have sufficient local (household or apartment complex) water storage. When asked if 24/7 piped supply would be implemented in Pune during the next 5 years, only two participants thought this would occur.

6. Flood Mitigation

Floods are a major hazard in the Bhima basin, particularly in Pune. Better integrated management is essential to save lives and property.

Although water provision in the region revolves around water storage and supply, in Pune people do not die from droughts, they die due to floods. Floods occur due to: heavy rainfall and cloudbursts, soil saturation, and inadequate storage in dams. Planning for flood management should start with imagining the worst-case scenario, but there is an innate contradiction between the goal of drought protection (reservoirs are full) to flood protection (reservoirs can cushion sudden heavy rainfall). Possible solutions discussed were integrated dam reservoir management involving the complex of dams servicing the entire Bhima basin, and better mapping of potential flood-risk areas. Impediments to better flood management involve: 1) making water releases and dammed reservoir storage management a technical decision rather than a political decision, and developing better management of reservoir storage for flood risk mitigation, 2) removing illegal encroachments, and 3) removing existing constructed developments. The latter was viewed as "impossible." There was seeming agreement that levees and embankments were a flawed idea as the can create flood problems in upstream and downstream regions.

Dredging of dams was suggested but it was noted that many of the reservoirs in the highlands are in basaltic rock terrain and do not suffer from much sedimentation. It was suggested that the actual water quantity in the dams should be available in real time to the public. Emergency disaster services were viewed as excellent, but people are unwilling to leave their households. A change in behaviour is needed. Finally, it was suggested that the FUSE project would be helpful by showing our water supply projections to local authorities to raise awareness of the current and future flood risks.

Working Group 2 Demand management and reallocation

The group discussion on demand management and water reallocation revolved around interventions in agriculture, urban interventions, and barriers to their implementation.

For the rural/agricultural interventions, the idea of shifting agricultural water use to the city was discussed through improving irrigation efficiency with smart farming practices and drip irrigation and shifting cropping patterns to less water-intensive crops. This means especially cultivating less sugarcane. Currently, sugarcane is heavily subsidized and shows other advantages to other crops, like low labor costs and high heat-resistance. Therefore, the stakeholders concluded that shifting the production to less sugarcane cultivation should be incentivized, also by assigning limited water rights. The instrument of crop insurance exists, but it is deemed ineffective to reduce water consumption, so it should rather be combined with water pricing and insurance that protect farmers from climate change impacts.

On the topic of urban interventions, several measures to enhance water availability in the city were brought up by the stakeholders, such as rainwater harvesting on roofs, wastewater recycling, and the use of greywater. For rainwater harvesting, the idea was to start on public buildings (PMC would already offer incentives for that). Concerning wastewater recycling, a decentralized system was favored by the stakeholders, whereby it was mentioned that decentralized sewage is mandatory for townships over 1000 inhabitants already. The early integration of adjacent villages to the sewage system was also expressed as a policy goal. Greywater use should also be incentivized, e.g., for the cooling of power plants.

Next to these interventions, the water pricing system as a regulatory tool to enhance the equitable access to water in Pune was discussed. Here, water metering is key. The idea was to implement an increasing tariff structure, with a free base volume and a volumetric payment based on further consumption.

As another price-based intervention, the concept of payment for ecosystem services, in terms of paying farmers to consume less water, which is then shifted to urban demand, was brought up. Here, the main barrier was seen in whether the willingness-to-pay of urban inhabitants would be sufficient. Finally, the general decentralization of urban growth in Pune through making agriculture more attractive and strengthening tier cities was seen as a tool to curb future urban water consumption in Pune.

Working Group 3: Dissemination and Outreach

The aim of the working group was to collect ideas on how to disseminate the FUSE research results and how to enhance local cooperation to build on the existing research.

The working group developed several ideas under the three topics “Knowledge, Practice and Policy”. Under the first topic, participants collected ideas on how to transfer existing knowledge and to further develop the FUSE-research in cooperation with local research institutions - e.g., by organizing courses at universities, to integrate the results in training sessions on systems thinking, or by initiating PhD projects. Under the second topic, ideas on disseminating results for a non-scientific audience were developed, such as organizing workshops in rural areas in cooperation with local organisations or producing booklets in Marathi. Under the topic “Policy”, ways how to organize dialogues with policy makers were discussed.

Step 6: Presenting Results and Concluding

After a presentation of results of the working groups, Dr. Himanshu Kulkarni from Acwadam presented his reflections about the FUSE research. He summarised key points as part of the synthesis:

Reflections by Himanshu Kulkarni, Acwadam

- *The zero-sum game: No evidence of short-term declines of levels, but surely the obvious case of reduced recharge. Does pipe/canal leakage make up for it to create the zero-sum against reduced infiltration and recharge?*
- *Many surveyed urban centres show a large extraction of groundwater. Pune is anomalous as it is a surface-water dependent city. And yet, the groundwater footprint for Pune is significant.*
- *The pricing of water cannot be seen in isolation from service delivery. No pricing increase is possible without better service. Inter-sectoral pricing also makes things complicated!*
- *It is necessary to look beyond the demand-supply gap. Water availability or lack of it brings in tradeoffs that must be seriously considered.*
- *The concept of comparing water footprints between rural and urban neighbourhoods bring out the iniquitous nature of demands and the differential weights of each type of demand.*
- *There is a need to standardise the units of measurement: in urban contexts, water is typically measured in TMC, in agriculture, it is usually mm or MCM.*
- *Our current models may need to be re-calibrated: thresholds of models, e.g. the 100-year benchmark for flood should be adapted to recent year events.*

Complementary outreach activities

After the core workshop days, members of the FUSE team engaged in various complementary outreach activities with support from workshop participants and local partners to further raise awareness for the project results and explore future research and collaboration activities. On the morning of July 21st, Maharashtra's Water Resources Department organized a tour of the Khadakwasla dam to give the FUSE team additional insights into the staff's approach to reservoir operation. In the afternoon, project representatives joined Dr. Himanshu Kulkarni's team at the Advanced Center for Water Resources Development and Management (ACWADAM) to explore future outreach and collaboration options.

On July 22nd, Prof. Gorelick and other members of the FUSE team were invited to present their results to Additional Municipal Commissioner Dr. Kunal Khemnar and other representatives of the Pune Municipal Corporation (PMC) to discuss their implications for PMC's urban development and water resource management plans. In the afternoon, the FUSE team joined GIPE Prof. Kailas Bavale on a visit to several local sustainability projects initiated by him in the Vadagaon Ghenand village. This included a discussion with students of the Dr. Dhanjayrao Gadgil Center for Sustainable Village Development and a field trip to a microshed water supply restoration project that has improved water availability in rural 150 wells, supplying water to more than 100 hectares of irrigated agricultural area around the village.

Images: *FUSE team visits to Khadakwasla dam (top), the Vadagaon Ghenand village council (middle), and a local microshed water supply restoration project (bottom). Photos: FUSE team, Prof. Kailas Bavale.*

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Organizations participating in workshops

12030 Water Resource Group
Advanced Center for Water Resources Development and Management (ACWADAM)
CCP Environmental Foundation
Center for Environment Education (CEE)
Green Tech Advisor
Centre for Sustainable Village Development
ExploreiT & Climate Reality
Gokhale Institute of Politics and Economics (GIPE)
Gomukh (Environmental Trust for Sustainable Development)
Graphics Solutions RA LTD
Indian Institute of Technology Bombay (IITB)
Indian Institute of Science Education and Research (IISER)
Initiatives for New Ecological Community Concerns (INECC)
Ira Sustainable Water Solutions
Jeevitnadi Living River Foundation
Mahrattra Chamber of Commerce, Industries and Agriculture (MCCIA)
Ministry of Commerce, New Delhi
Mission Groundwater
Marathwada Mitramandal's College of Architecture (MMCOA) Pune
Mahatma Phule Krishi Vidyapeeth (MPKV)
Punarbharan Foundation
Pune International Centre
Pune Knowledge Centre (PKC)
Pune Municipal Corporation (PMC)
Samuchit Énviro Tech
Society for Environment Education Research and Management (SEERAM)
Society for Promoting Participative Ecosystem Management (SOPPECOM)
Sustainable Living Integrated Solutions
Symbiosis Centre for Climate Change & Sustainability (SCCCS)
Symbiosis Centre for Management Studies (SCMS)
The Nature Conservancy
Tata Research Development and Design Centre (TRDDC)
Vasantdada Sugar Institute (VSI)
Vasundhara Swachata Abhiyan (VSA)
Water and Land Management Institute (WALMI)
Water Resource Department (WRD) Maharashtra
Watershed Organisation Trust (WOTR)

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