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Planning for Livelihoods Under Hydrosocial Uncertainty in Periurban Pune

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Periurban farmers in India are operating in fast-paced transformative environments of uncertain, quickly changing hydrosocial landscapes while simultaneously responding to different urban, rural and periurban demands. The urge is growing toward a more sustainable, integrative agricultural transformation, in which local stakeholders have more agency to control their own development. Yet, farmers are mostly passive in the process of shaping periurban futures as they face challenges in dealing with growing uncertainties in their hydrosocial environments. From a political ecology perspective, the concept of the hydrosocial cycle helps in understanding these uncertainties and their impacts on farmers' livelihoods and in classifying water-society dynamics. We adopted this concept to critically assess different perceptions of uncertainties based on the effects of uneven hydrosocial development. Extending beyond this analysis, we then followed a multi-perspective, scenario-based planning approach to show a methodology to support farmers in adapting and planning accordingly. We applied a modified Delphi method that combines local knowledge of actors from the village Paud in periurban Pune (India) with the expertise of Indian and international experts. We used the method to determine actions and institutions for different future scenarios and to understand which drivers and signals interfere and affirm each scenario's feasibility. From both bodies of knowledge, we could identify one realistic preferred/business-as-usual scenario and two alternatives with eight different drivers that cause complex, hydrosocial uncertainties. Both bodies of knowledge suggest that farming will continue to be an important water-based livelihood in Paud in the future. Yet, we were able to contrast different mechanisms involved in the future thinking of actors and experts. This research contributes to understanding possible processes of adaptation through co-creation of knowledge. The applied methodology can enable farmers to reflect on possible futures, activate their available capabilities, and may facilitate more sustainable and adaptive decision-making. After further refinements, the method employed could in future be useful for policy making and planning.

Keywords: periurban agriculture, hydrosocial uncertainties, water-based livelihoods, scenario-based planning, adaptive decision-making, Delphi, periurbanization, hydrosocial cycle

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INTRODUCTION

Periurban farmers are under pressure to respond to permanently changing demands between providing food, livelihoods, and ecosystem services and are often reactively rather than actively shaping their futures (Hussain and Hanisch, 2014; Gumma et al., 2017; Butsch and Heinkel, 2020; Follmann et al., 2021). This is related to their embeddedness in uncertain changing hydrosocial patterns and governance structures (Allen, 2003; Vij and Narain, 2016).

Periurban agriculture is driven inter alia by global food systems integration (Hussain and Hanisch, 2014), land conversion (Allen, 2003; Yang et al., 2016; Follmann et al., 2021), urbanization and population pressures (Gumma et al., 2017; Follmann et al., 2021), and internal reconfigurations, e.g., local resource competitions (Gumma et al., 2017; Punjabi and Johnson, 2018; Butsch and Heinkel, 2020), or unequal capitalization of farmers (Hussain and Hanisch, 2014; Narain, 2014). Within these processes, the quality and quantity of water, the natural and socio-politically-constructed access to water, and the distribution and control of water change. In addition to its importance as a direct source of agricultural productivity (Curmi et al., 2014), water is increasingly understood as an object of uneven power relations (Bartels et al., 2018). Due to periurbanization, the hydrosocial environment (Swyngedouw, 1999, 2009) is shifting and restructures farmers' practices. Some aim to intensify their cultivation patterns to scale up production (Hussain and Hanisch, 2014; Vij and Narain, 2016). However, their income-to-expenditure-ratios often become unbalanced due to expensive labor, land values, or agricultural inputs, frequently leaving them in debt (Hussain and Hanisch, 2014). Others decide to withdraw from farming, refocusing on higher education (Hussain and Hanisch, 2014; Gumma et al., 2017; Follmann et al., 2021) or finding alternative employment (Srinivasan et al., 2010; Thomas et al., 2017).

A practical challenge of hydrosocial restructurings in periurban areas is the governability of farming, which is aggravated by confined, multi-scalar structures. As periurbanization processes continue, hydrosocial systems change toward new power constellations, and traditional rural institutions lose strength while salient hierarchies and legacies remain. Simultaneously, the periurban becomes immersed in an institutional urban-rural vacuum with space for new actors to emerge (Punjabi and Johnson, 2018; Butsch and Heinkel, 2020). The management of periurban spaces as mosaics between parallel, but often contrasting, urban and rural contexts is thus institutionally fragmented and weakened (Allen, 2003). These dynamics multiply systemic uncertainties for hydrosocial systems, especially for farmers as vulnerable livelihood group.

The need for governance formats that engage local stakeholders in participatory, decentralized policy-making processes with control over their own development has been repeatedly addressed (Yang et al., 2016; Mitra and Banerji, 2018; Punjabi and Johnson, 2018) and requires a shift toward stronger public integration (Bruns and Gee, 2009; Molle et al., 2009; Bruns and Frick, 2014). Adaptive decision-making based on reflexive long-term action has been identified as crucial in this process (Beckford and Barker, 2007; Moyo, 2009; van der Molen, 2018). In agriculture, the effectiveness of local knowledge integration in governance has been proven where the accumulation of social capital has enabled farmers to form cooperatives and strengthen their agency (Rakodi, 1999; Hussain and Hanisch, 2014; Yang et al., 2016). Yet, local stakeholders often lack the means for knowledge transfer (Anik and Khan, 2012) which impedes its integration into governance. Local knowledge is thus often side-lined in favor of higher-level assertive expertise. This knowledge divide (Agrawal, 1995; Carolan, 2006) needs to be substantively, methodologically, and contextually bridged (Bohensky and Maru, 2011; Jahn et al., 2012) to enable complementary integration into local governance.

Against this background, this paper describes one approach toward supporting farmers' adaptive decision-making through the integrative design of transformation processes (Maru et al., 2014). Based on the concept of the hydrosocial cycle (Budds et al., 2014; Linton, 2014), we deconstruct and analyze the dynamic production of hydrosocial uncertainty in agriculture. Using a multi-perspectival scenario-based planning approach (Perveen et al., 2017), we then explore how more sustainable future decision-making can be co-produced. We apply a modified Delphi method pursuing two methodological strands to close the local-expert-knowledge-gap (Tapio et al., 2011; Fletcher and Marchildon, 2014; Perveen et al., 2017) by addressing actors in the village Paud, in periurban Pune as well as Indian and international experts and demonstrate a way to integrate local knowledge into livelihood-related governance. Tapping into two different knowledge systems allows us to discuss the questions of how adaptive capacity can unfold in a dynamic environment and which actions and institutions can support farmers toward more sustainable periurban futures. Through different scenarios, we examine the agency of famers as active participants in their own development and the role that new means of decision-making could play in enabling them to shape their hydrosocial environment.

The paper is structured as follows. The next section outlines the concept of the hydrosocial cycle, describes the uncertainties arising from social-ecological relations, and presents the scenario-based approach. Section "Materials and Methods" describes the modified Delphi method and how we reflexively applied it by combining local and expert knowledge. The section "Periurban patterns in Paud" gives a brief overview of the study area and in the section "Periurban futures" the results are presented. The "discussion" highlights the interrelationships between the different knowledge systems in terms of adaptive decision-making by farmers and reflects on the methodology before the conclusions are drawn.

SCENARIO-BASED PLANNING FOR HYDROSOCIAL SYSTEMS UNDER UNCERTAINTIES

Uncertainties are caused by social complexities (Versteeg et al., 2021), unpredictable drivers (Rikkonen et al., 2006), large-scale trends (Moors et al., 2011), or historic-systemic development

(Vermeulen et al., 2013; Versteeg et al., 2021) and co-create dynamic transformation processes. The understanding of uncertainty is shaped by these processes and manifests on multifaceted hydrosocial scales, e.g., through population pressure or pressure on resources (Ruet et al., 2007; Srinivasan et al., 2010; Prakash, 2013; Gumma et al., 2017).

In this section, we use the concept of the hydrosocial cycle to analyze uncertainties to which periurban farmers in India are exposed. We then address ways of counteracting these uncertainties through scenario-based planning for adaptive decision-making.

A Hydrosocial Perspective on Periurban Agriculture

The concept of the hydrosocial cycle is grounded in political ecology and was decisively shaped by Linton (2014) and Budds et al. (2014). In this concept, water is considered as constructed through dialectic societal processes with people and politics at the center of water-related issues reaching beyond its purely natural-physical character (Swyngedouw, 2009; Budds et al., 2014; Irvine et al., 2016). Water has a hybrid, context-specific meaning determined by interdependent practices (e.g., water for drinking, livelihoods) (Budds et al., 2014; Butsch et al., 2021), political-motivated decision-making, power relations, institution and governance (Swyngedouw, 2009; Budds et al., 2014), and hydraulic technology and infrastructure (Bakker, 2012; Linton, 2014; Irvine et al., 2016). It is determined by competition, conflicts, and power struggles over access and use by different stakeholders, who construct and reciprocally influence the hydrosocial merit of water through interrelated socio-ecological processes (Budds et al., 2014). Under the presumption that water is part of society's fabric, the concept addresses resulting vulnerabilities, adaptive capacities, and accesses in the water-based environment (Irvine et al., 2016). In the periurban, the hydrosocial cycle is in constant flux and perennially (re)shaped by multiple water-related contexts of livelihoods, institutionalization, pressure from population growth, and new infrastructures (Butsch et al., 2021). This dynamic landscape produces uncertainty about the status quo and the future, especially for local farmers as vulnerable and water-dependent livelihood group (Irvine et al., 2016; Butsch et al., 2021).

Periurban farmers in India are exposed to hydrosocial uncertainties in two ways (**Figure 1**): (1) Restricted access to water (e.g., due to climatic variability, insufficient hydraulic infrastructure, lack of access rights) causes stress on available resources and immediately affects farmers. This stress also creates secondary effects on local food security and drinking water supply and intensifies through rising urban demand for water and food (de Vries et al., 2007; Díaz-Caravantes, 2012; Butsch and Heinkel, 2020; Follmann et al., 2021) and resource competition with other water-based livelihoods. These developments result in unsustainable water usage, conversion of arable land, and disappearing water-based environments (Moors et al., 2011; Hussain and Hanisch, 2014; Thomas et al., 2017), contributing to major insecurities for farmers' livelihoods.

(2) Periurban water distribution is managed by multiple institutions. *Gram panchayats* (self-governing village bodies) politically and administratively manage water issues and oversee local councils and committees. Irrigation departments on the district level are responsible for distributing water for agricultural use. These existing structures are often ill-equipped to efficiently operate within constantly altering hydrosocial dynamics (Butsch et al., 2017; Hui and Wescoat, 2019). New institutions emerge but often do not have the required effectiveness to support local needs (Gomes et al., 2018b). As counteraction, farmers trade-off higher level hydro-political processes, village collective initiatives, and their individual capacities to access responsive hydraulic infrastructures (Versteeg et al., 2021) and thereby increasingly drift into hydrosocial insecurities. Exposure to these hydrosocial uncertainties increases farmers' vulnerability in a highly transformative environment, challenges adaptive decision-making processes (Maru et al., 2014) and thus calls for new measures and water resource planning (Moors et al., 2011).

Scenario-Based Planning in Adaptive Decision-Making

Scenario-based planning helps in understanding long-term uncertainties and complex volatilities and how their development can influence a specific system over time (Rikkonen et al., 2006; Giaoutzi et al., 2012; Wulf et al., 2013; Versteeg et al., 2021). The degree of uncertainty is determined by the number of possible scenarios. The higher the number of scenarios, the greater the uncertainty (Godet, 2000).

Scenario-based planning is generally applied in two ways. First, as a planning tool, it supports adaptive decision-making under uncertain conditions (von der Gracht and Darkow, 2010), broadens the perception of possible developments (Wulf et al., 2013) and thus allows dynamic future designs to be explored (Rikkonen et al., 2006; DasGupta et al., 2019). Second, as a social learning tool, it facilitates understanding contexts and identifying and developing adaptive future paths and coping mechanisms and permits an informed selection and execution of broader strategies with full awareness of the consequences of actions (Rikkonen et al., 2006; Giaoutzi et al., 2012; Wulf et al., 2013; Galafassi et al., 2018; Garteizgogeascoa et al., 2020). Giaoutzi et al. (2012) consider it an interactive instrument to facilitate engagement in change processes and theory-to-practice translation for policy makers, stakeholders, and the public. Godet (2000) distinguishes between explorative scenarios describing future trends and normative scenarios focusing on desirable and apprehensive future visions designed in retroprojection.

In the literature, scenario-building is commonly described as a three-step process. First, the current status quo is identified to guide prospective thinking in alternatives (Godet, 2000; Rikkonen et al., 2006; von der Gracht and Darkow, 2010; Perveen et al., 2017). Second, systematic, incremental visualization and description and logical progressions of hypothetical events and actions are sequenced (Rikkonen et al., 2006; von der Gracht and Darkow, 2010; Tapio et al., 2011). Third, the appropriateness

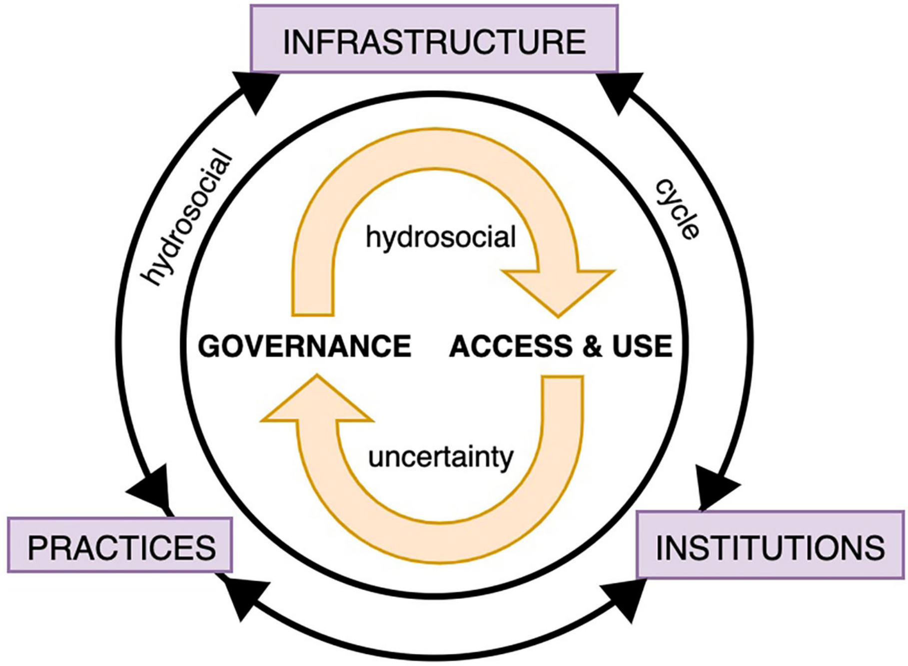

FIGURE 1 | The production of hydrosocial uncertainty.

of strategies and planning is examined and reflected on the basis of future alternatives (von der Gracht and Darkow, 2010; Perveen et al., 2017). Based on this, Wulf et al. (2013) differentiate six phases for scenario-building. First, they define research elements key to preparing the process. Second, they determine the stakeholders and their future perceptions. Third, they identify trends, uncertainties, and drivers leading to different future alternatives. Fourth, they build descriptive scenarios that link present conditions to future outcomes through sequenced steps. Fifth, they reflect on the scenarios' feasibilities. Sixth, they monitor and assess whether adaptations or changes are necessary.

Scenario-based planning is becoming increasingly important for investigating socio-ecological transformation (Oteros-Rozas et al., 2015) and is popular among politicians and planners operating under highly complex and dynamic conditions (Harrill, 1999; Moors et al., 2011; DasGupta et al., 2019). It has been applied in environmental, economic, and social mitigation in urban planning (Perveen et al., 2017), in planning for agriculture (Vermeulen et al., 2013), land-use changes (DasGupta et al., 2019), or water management (Versteeg et al., 2021). It has two advantages. First, it integrates disparate capacities and prevents the emergence of unequal knowledge systems (Taylor and Ryder, 2003). Second, it equips policy makers with informed knowledge on potential long-term impacts and risks and helps prioritizing the feasibility of future options (Rikkonen et al., 2006; Giaoutzi et al., 2012; Vermeulen et al., 2013). Scenario-based planning, thus, facilitates capacity development to identify opportunities and threats of long-term actions and policies (Rikkonen et al., 2006; Perveen et al., 2017).

For the purpose of our study, combining a scenario-based approach with fundamental ideas from political ecology requires a twofold thought process. First, the political ecology perspective is applied in a critical, analytical way to investigate relevant elements of complex, and often historically produced, hydrosocial systems, change processes, and which uncertainties arise from them. However, political ecology does not foresee a proactive way of effectively applying and disseminating obtained findings in order to identify future alternatives (Walker, 2006). Second, we therefore complement the political ecology perspective with a scenario-based planning approach in a normative, inclusive, solution-oriented way (Oteros-Rozas et al., 2015). Scenario-building enhances co-productive social learning, through which socio-ecological complexities and corresponding adaptation measures are participatorily developed to inform decision-making (Oteros-Rozas et al., 2015; Galafassi et al., 2018; Garteizgogeascoa et al., 2020).

MATERIALS AND METHODS

Incorporating impact- and capacity-driven perspectives on adaptive decision-making, we integrated spatially differentiated, multi-perspective, transdisciplinary engagement (Vermeulen et al., 2013; Versteeg et al., 2021) in a three-staged, modified Delphi method. The following section outlines the principles of this approach. We then explain the access to information under restrictive conditions of the ongoing COVID-19 pandemic[1]. Then, we outline the implementation of the methodological steps using reflexive, newly developed tools.

[1]The originally planned participatory on-site research could not be implemented due to the COVID-19 pandemic. We therefore developed digital, remote means for data collection and interacting with local actors and with the experts involved.

Principles of the Delphi Method

The Delphi method is a tool for forecasting, decision-making, and scenario-based planning to gain projections and expertise on uncertain, often undefined futures (Tapio et al., 2011; Davidson, 2013; Fletcher and Marchildon, 2014; Perveen et al., 2017). Since its first implementation in the 1960s by Dalkey and Helmer (Fletcher and Marchildon, 2014), the method has evolved into a publicly-applied forecasting technique (von der Gracht and Darkow, 2010; Landeta et al., 2011). It is applied in multiple fields (Fletcher and Marchildon, 2014), e.g., environment, sustainability (Taylor and Ryder, 2003), urban growth management, economics, infrastructure or climate change (Perveen et al., 2017). The Delphi method is a multifaceted approach with numerous modifications. Tapio et al. (2011) distinguish between a Disaggregative Delphi (no consensus, multiple alternatives) and a Policy Delphi (preferences disagreement). Davidson (2013) introduces a Policy Delphi for identifying ideologies of political actors and a Decision Delphi for social-contextual decision-making. Fletcher and Marchildon (2014) classify a conventional solution-oriented format with strong standardization, a single meeting, time compressed format, and a policy-oriented format for decision-makers.

Delphi studies have four common characteristics. (1) Anonymity allows a non-biased, unrestricted expression of opinion, influence, or domination by (dis)agreement from other panelists. In subsequent rounds, panelists can, without justification, modify previous statements as a response to other opinions (Rowe and Wright, 2001; von der Gracht and Darkow, 2010; Siegrist and Gessner, 2011; Davidson, 2013; Perveen et al., 2017). (2) Iteration allows for progressively addressing aspects over a longer period (Rowe and Wright, 2001; Siegrist and Gessner, 2011; Davidson, 2013; Fletcher and Marchildon, 2014). The number of rounds depends on the objectives (Davidson, 2013). (3) Controlled aggregated feedback on the group opinion is provided in each round to indicate consensus and disagreement and to identify central tendencies (von der Gracht and Darkow, 2010; Trevelyan and Robinson, 2015). (4) Group opinion is assembled from each individual answer and contributes to the final results. The group resonance is presented numerically or graphically and enables the panelists to recognize their opinions and place them in the collective picture (von der Gracht and Darkow, 2010; Landeta et al., 2011).

The quality of the Delphi method is primarily determined by the criteria of consensus and stability. Consensus on reaching (dis)agreement implies a group opinion, consent on a statement, or merely a pre-defined convergence. Stability of responses is often considered the more important criterion as it takes into account the changes, consistency, and reliability of group opinions throughout the process (von der Gracht and Darkow, 2010; Trevelyan and Robinson, 2015; Perveen et al., 2017). However, consensus and stability are often solely used as indicators for ending the process (Rowe and Wright, 2001; von der Gracht and Darkow, 2010; Trevelyan and Robinson, 2015).

A Modified Delphi Method for Scenario-Based Planning

Two aspects make the Delphi method suitable for scenario-based planning. First, scenario elements can always be adapted iteratively and qualitatively reconfigured. Second, because multiple stakeholders are involved, opinions are progressively contrasted and initiate a rethinking process based on different knowledge systems (Rikkonen et al., 2006; von der Gracht and Darkow, 2010).

Our methodology was inspired by these considerations: To cover a broad cross-section of participants, we used a structured approach to tailor our approach to the panelists' knowledge of and familiarity with the research area and equally acknowledged their perspectives and credentials (Rowe and Wright, 2001; Landeta et al., 2011; Siegrist and Gessner, 2011; Tapio et al., 2011; Perveen et al., 2017). Since the Delphi method does not necessitate traditional face-to-face interactions, we could integrate geographically-dispersed panelists (Rowe and Wright, 2001; Day and Bobeva, 2005; Siegrist and Gessner, 2011; Davidson, 2013; Fletcher and Marchildon, 2014; Perveen et al., 2017). We executed three rounds of the method, in spite of restricted access to the research field.

Combining Local and Expert Knowledge

The two epistemological spheres of local and expert knowledge[2] were, for long, not considered as equivalents. Yet, today an integrative approach is more commonly used, e.g., to understand vulnerabilities from and adaptations to climate change impacts (Anik and Khan, 2012). Research on agriculture builds on the local-expert-compatibility within which, to contribute to food security, it examines farmers' reflexive responses to changing environments (Moyo, 2009), participatory risk management (Oliver et al., 2012) or their understanding of local resources (Beckford and Barker, 2007). In our study, both knowledge systems are valued equally to create means for adaptive decision-making based on local-expert-knowledge-integration (Oliver et al., 2012).

In our study, local knowledge represents a detailed understanding of site- and time-specific developments and challenges (Agrawal, 1995) used for effective, morally appropriate solutions (Smith, 2011) based on local value systems, needs, and aspirations (Moyo, 2009). Local knowledge is understood as "dynamic and complex bodies of know-how, practices and skills that are developed and sustained by peoples/communities with shared histories and experiences" (Beckford and Barker, 2007, p. 118). As it undergoes constant modification, e.g., through livelihood changes (Agrawal, 1995), tapping into local knowledge pools means creating reflexive, adaptive information (Beckford and Barker, 2007; Moyo, 2009; Maru et al., 2014). To cover these dynamics, we formed a panel of 16 actors with different livelihoods (service, fisheries, agriculture, artisan crafts), institutional affiliations (*gram panchayat*, local associations),

[2]Local knowledge designated as non-scientific, communally-produced, indigenous, or traditional knowledge and expert knowledge designated as theoretical, non-localized, (scientifically), verified knowledge (Agrawal, 1995; Bohensky and Maru, 2011).

households, gender, and age categories from Paud. To achieve a high degree of inclusive empowerment (Agrawal, 1995; Smith, 2011) and create active engagement for accommodating local knowledge (Oliver et al., 2012), an enumerator team from the Bharati Vidyapeeth Institute for Environmental Education and Research (BVIEER) in Pune worked in direct exchange with the actors. They translated the material into the local language Marathi and implemented data collection through telephone interviews. The process was coordinated by the authors.

In our study, the epistemological difference is used to distinguish local knowledge from expert knowledge, which is used to assess reality and the level of abstractness on specific topics of interest (Agrawal, 1995). Experts are considered to be higher-ranking professionals with professional expertise, technical knowledge or scientific influence and work in integrated networks (Flick, 2014). For our study, we formed a panel of 18 Indian and international experts representing regional expertise, different affiliations (academia, institutions/research, NGOs, planning) and research interests (livelihoods, environment, planning, policy and governance, water management, periurban development, geography). The experts were contacted through researchers from the TUDelft, the research organization SaciWATERs (Hyderabad) and the University of Cologne. In the text below, the two different sources of knowledge will be referred to as actor strand and expert strand.

Toward Building Scenarios

In the joint project "H2O – T2S in urban fringe areas," we investigate water-based transformation processes in the periurban areas of three Indian metropolises (Pune, Hyderabad, Kolkata). We specifically explore the plurality and contexts of water-based livelihoods, water as a consumption good, and water-related institutions and governance to understand site-specific vulnerabilities and capacities and facilitate long-term planning opportunities for potential alternative periurban futures. For this purpose, we implemented the six phases of scenario-building (Wulf et al., 2013) in three rounds[3] of interaction between December 2020 and October 2021 (Actors: Round 1 from Dec 2020 to Feb 2021, Round 2 from Mar 2021 to Jun 2021, and Round 3 from Jul 2021 to Oct 2021; Experts: Round 1 from Jan 2021 to Feb 2021, Round 2 from Apr 2021 to Jun 2021, and Round 3 from Jul 2021 to Oct 2021).

In the first round, we captured normative scenarios regarding future village developments based on the understanding of contemporary hydrosocial uncertainties. In the second round, these scenarios and their constituent elements were prioritized and specified. We determined actions and strategies (Enserink et al., 2010; Marchau et al., 2019), institutions and institutional actors (Gomes et al., 2018a,b), and different value systems (Keeney, 1996; Cunningham and Hermans, 2018), and assessed uncertainty caused by challenges and drivers (Maru et al., 2014). In the third round, the scenarios were sequenced into an action and institution-oriented format to reflect possibilities to plan under uncertainties based on ideal and alternative scenarios (**Figure 2**). In more detail:

In the actor strand, we conducted structured interviews (Bernard, 2006) via telephone and WhatsApp. The actors received an overview of the questions prior to each round. To prepare for the first round, they received a video on the current status quo in Paud illustrating specific village developments, based on previous research findings (Butsch et al., 2021). For the subsequent rounds, short aggregated feedback-videos were prepared to disclose previous rounds' results.

In the first round, we clustered differentiated "ideal," "nightmare," and "business-as-usual" future visions on Paud's development until 2035. Using the local actors' insights on value systems, actions and strategies, institutions and drivers, we identified eight different scenarios. In the second round, these scenarios and their constituent elements were prioritized according to desirability. The drivers were assessed according to the likelihood of their occurrence and the possibilities of adapting to them and coupled with signals that announce tipping points (Hermans et al., 2017). Initial institution and action-based decision-making paths could be sketched, marking the business-as-usual and possible alternatives from the current situation to the future. The third round was used to reflect, confine, and assess the scenarios' feasibilities under the emergence of specific drivers. Previously defined signals and tipping points were narrowed

[3]Panel sizes were reduced to 16 expert-strand participants and 15 actor-strand participants in the second round and 14 participants in both strands in the third round.

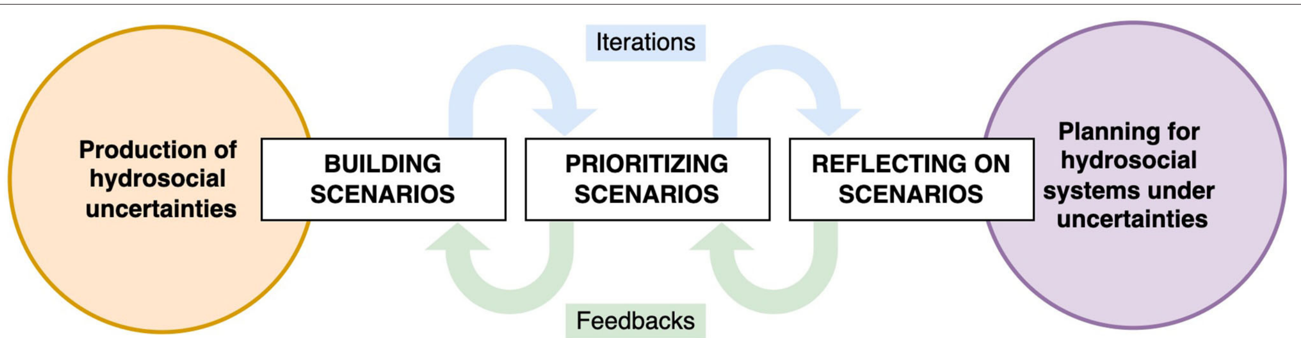

FIGURE 2 | Analytical framework for scenario-based planning under hydrosocial uncertainties.

down and linked to transfer stations toward alternative pathways (Haasnoot et al., 2018).

In the expert strand, the projects' objectives and a video on the status quo of Paud's village development were provided. The village's actual identity was not disclosed. Paud was presented in an abstracted version as a periurban model village. In contrast to the actor strand, the experts were asked to exclusively focus on the most sustainable future to improve on the current business-as-usual in the village. The first round was conducted via digital semi-structured qualitative interviews. These interviews were recorded, transcribed, and anonymized (Bernard, 2006). The second and third rounds were executed via structured online surveys generated with LimeSurvey. In these rounds, aspects about the model village were recalled and the panelists were informed about the results of the previous rounds.

In the first round, we classified normative scenarios of sustainable village development, livelihoods, household water situations, and institutions in terms of value conception, actions and strategies, institutions and institutional actors. In the second round, these scenarios and their constituent elements were prioritized according to desirability and the roles of institutional actors were specified. Challenges and drivers of village development were classified with their associated signals (Hermans et al., 2017). Initial institution and action-based decision-making paths could be sketched, marking a possible path of actions from the current situation into a more sustainable future. The third round was used to reflect, confine, and assess the scenarios' feasibilities under the emergence of specific drivers. Previously defined actions and strategies, institutions and signals were specified, narrowed down and linked to challenges and their tipping points toward alternative pathways (Haasnoot et al., 2018).

The iterative nature of the Delphi method includes an inherent validation of the credibility of the actors' and experts' statements in each round. In addition, interim results were discussed among the research partners and with the local enumerator team to check the validity of statements. Due to the COVID-19 pandemic, the final results could not be shared in a face-to-face dialogue. For the actors, the results were summarized into videos and shared through the enumerators. For the experts, the results were shared digitally in a final closing conference.

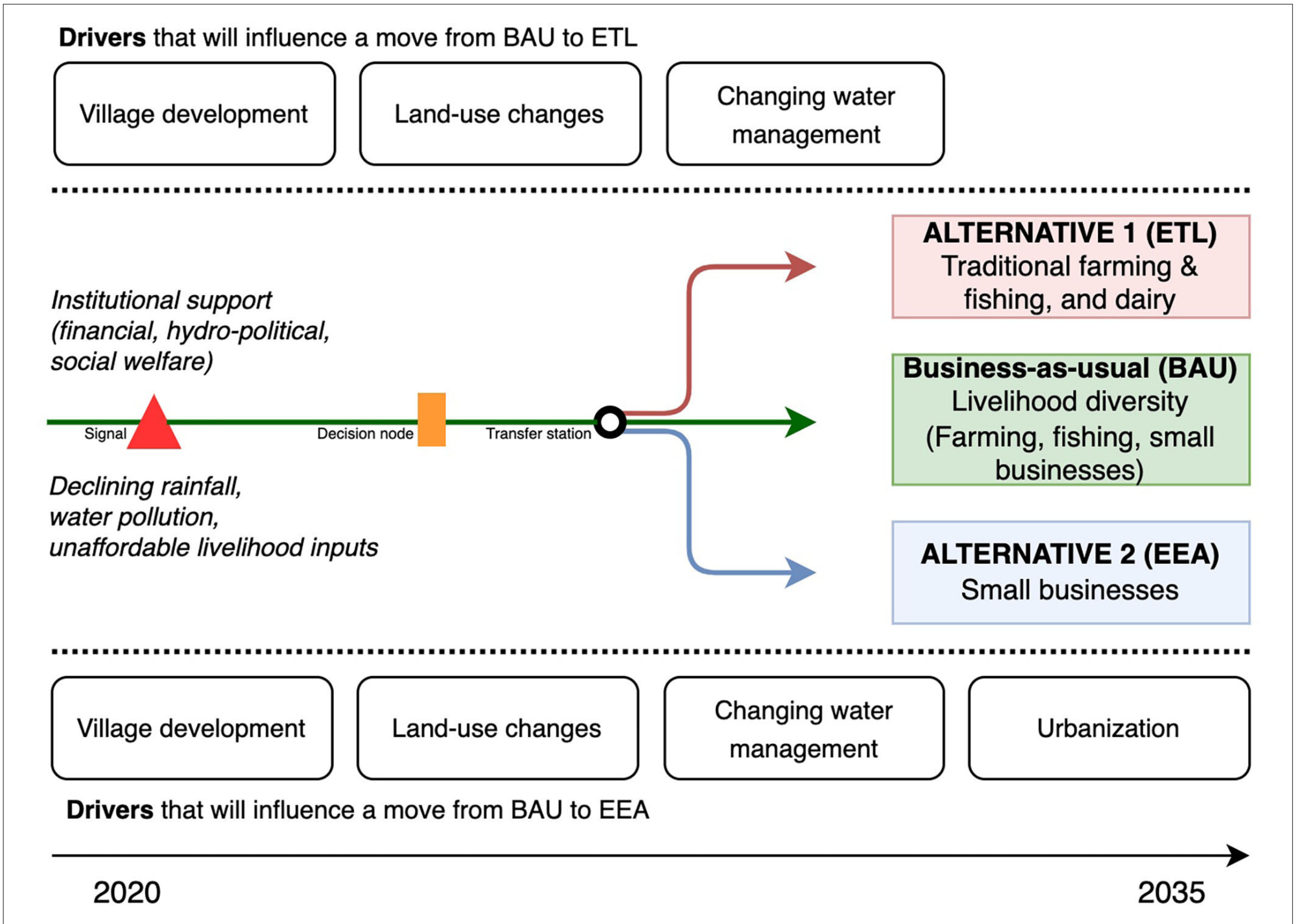

FIGURE 3 | Actors' view on future livelihood scenarios.

HYDROSOCIAL PATTERNS IN PAUD

Paud (4,000 inhabitants) is located West of Pune (30 km) in the Western Ghats, south of the river Mula, which flows from the Western Ghats toward Pune (Butsch et al., 2021). Farming, foremost paddy cultivation, is one of the major water-based livelihoods. In 2011, 18% of the residents were engaged in farming (Butsch, 2019).

As a result of various historical hydrosocial dynamics, farming patterns in Paud have changed significantly over the last 50 years. With the intensification of agricultural production (Green Revolution), the initial waterscape was altered as a result of technical and social changes. The hydrosocial structures were repeatedly changed, modernized, and expanded and their access became more exclusive. Originally, farming was determined by annual rainfall. Nowadays, it is risky for farmers to rely on precipitation due to increased variability and the changing varieties of crops in recent years. Water availability strongly depends on financial means to access water. Many farmers have invested in hydraulic systems through which water is drawn from the river or pumped from groundwater resources and used for irrigation.

These hydrosocial alterations have created pronounced power gradients and water-user hierarchies. Official support systems, institutions, and formal farmers' associations are not in place. As a result, informal associations of neighboring farmers have emerged, e.g., to share water access or equipment. But the prevailing formal vacuum has also reinforced arbitrary, micro-political power structures by making lower-capital farmers more dependent on capital-stronger farmers, especially in terms of land and water appropriation. The competition over water, as a basic resource for farming, increases not only within the peasant community but also with other water-based livelihoods, e.g., pottery or fishing, as coexisting, traditional occupations or newly emerging water-based economic activities. As a result, farmers stand between withdrawal and intensification and face uncertain futures.

As agricultural land is increasingly transformed into urban structures, urbanization pressures further affect farmers, with both land-use patterns and existing water systems being altered (Diddee and Gupta, 2000; Wagner et al., 2013). These dynamics are already evident in Paud as a result of Playtor, a multistorey township with an expected capacity of 900 flats anticipated to contribute to displacing traditional village structures (Butsch et al., 2021).

PERIURBAN FUTURES

The two types of knowledge provide multiple insights into potential futures in Paud. The following section presents the outcomes of the modified Delphi method separately. By first concentrating on the actor strand and second on the expert strand, we discuss the scenarios and their drivers and explain which actions and institutions shape them.

Scenarios Created by the Actor Strand

The actors developed three different livelihood scenarios for Paud. The "business-as-usual" scenario (BAU) foresees livelihood diversity including farming, fishing, and small businesses. The first alternative scenario, the "extended traditional livelihoods" scenario (ETL), includes traditional water-based livelihoods (farming, fishing) and dairy farming. The second alternative scenario, the 'extension of economic activities' scenario (EEA), focuses on small businesses (**Figure 3**). Four drivers are expected to affect these scenarios. "Village development," "urbanization," "changing water management," and "land-use changes." They have both positive and negative implications. "Village development" is most likely to affect livelihood-regarded actions and institutions. It leads to employment opportunities, better education, active participation in local politics, and transparency in governmental action. Most actors think that 'village development' will transform the village into a town and causes the greatest uncertainties, yet with a more positive long-term impact. "Land-use changes" can result in natural environmental protection but also trigger the privatization of land and increase construction activities. The drivers "changing water management" and "urbanization" are expected to negatively impact livelihoods. Farmers and members of the *gram panchayat* anticipate that "urbanization" will bring instability.

"Changing water management" and "land-use changes" are the first drivers expected to affect Paud within the next five years and to continue for the next 10 years. The drivers "village development" and "urbanization" are not expected to start affecting Paud immediately but in the foreseeable future (in five years). They are expected to have a long-lasting impact. Each driver is announced by distinct signals leading to one of the three livelihood scenarios.

The "Business-as-Usual" Livelihood Scenario (BAU)

In the BAU, the present village dynamic continues as it is and leads to a diversification of livelihoods with farming, fishing, and other water-based and non-water-based livelihoods. Traditional livelihoods continue to exist but will diminish. Some households slowly leave their traditional occupations and orient toward small-scale businesses (e.g., car wash, small shops). Initially, traditional livelihoods continue unchanged, due to local and urban demand for traditional products. Households are supported with structured assistance, e.g., financially through government funding to intensify their production, and also through new educational opportunities. This double-track future is described by a farmer: "The young generation should focus on education, but shouldn't go away from their motherland and should know about how to do farming, because food is a nursery need and money is not [. . .] I will not sell my land as he [his son] will be doing agriculture as well as his job in future. I don't want my future generation to quit farming and I think it's the same for the others." The BAU continues with more households selling their land as pressure from external building increases, access to local water resources becomes more restrictive and traditional livelihoods increasingly become unviable. A member of the *gram panchayat* explains: "People don't invest their own money to create a pipeline from the river and focus on agriculture as they were doing before."

According to members of the peasant community, targeting economic viability through new businesses reinforces the hydrosocial competition, especially with farmers as the main water-users among the livelihood groups, and exacerbates the degradation of water resources. A local water infrastructure provider describes: "Looking at the present situation: rivers are polluted. And in the future, they will be more polluted." The BAU, thus, indicates many uncertainties, especially for farmers. However, most of the actors consider it the most likely future for Paud.

The Alternative Livelihood Scenarios

The actors consider the ETL to be the first alternative livelihood scenario. The decision to shift to this scenario may be taken if institutional support for agriculture and fisheries is signaled. This support includes institutionalized financial assistance, e.g., for subsidized equipment, hydro-political implications, e.g., protection of local resources, mediation of conflicts over resource use, and social welfare, through the security of local market access or the creation of livelihood-specific associations. This support could potentially be provided by multiple actors, e.g., the state government of Maharashtra and the district administration in collaboration with the *gram panchayat*. With this kind of support, farmers state that they would be "able to practice traditional livelihoods properly" (farmer from Paud), or even upscale to dairy farming. Six specific actions are important in the ETL:

(1) Equally allocating local resources to increase yields;
(2) Receiving and using financial support to upgrade product scale and patterns;
(3) Reducing pollution of soil and water bodies;
(4) Increasing local consumption to resist outside competitors;
(5) Increasing political engagement and a sense of community to mediate conflicts and strengthen the local economy;
(6) Developing markets and increasing access to outside markets.

Figure 4 shows each of the actors' responses in a line sequence of up to three actions from left to right in the ETL. For instance, Actor 4 envisions "allocating local resources" as first action, "receiving and using financial support" as second action and "pollution reduction" as third action. Each transfer station represents the shift to the next action. The thicker lines in the diagram represent consensus on the most important actions and their sequencing. The most important first actions are "receiving and using financial support" in combination with "allocating local resources" and "increasing local consumption to resist outside competitors." All of the suggested actions except "pollution reduction" and "allocating local resources" are considered important second steps. These actions include "receiving and using financial

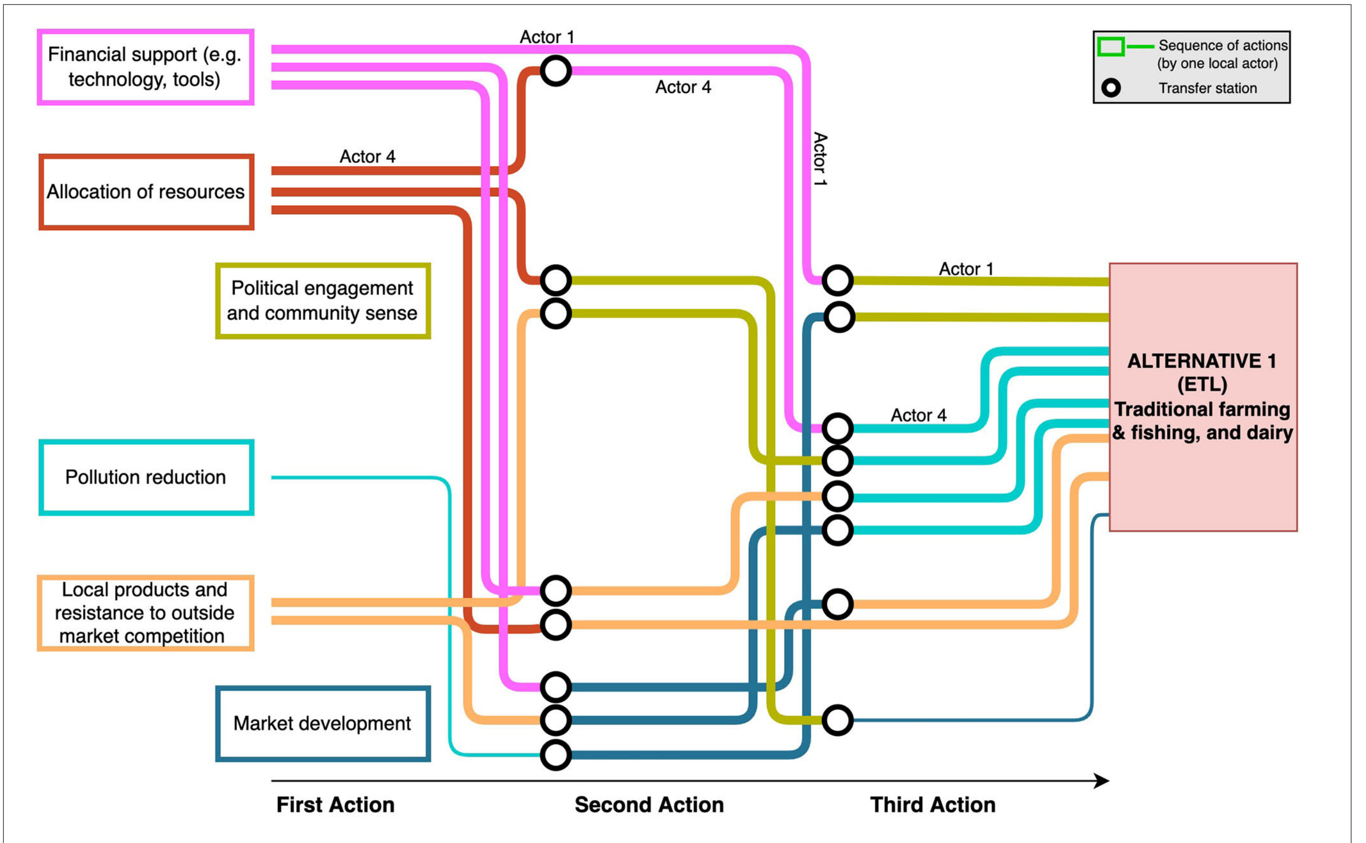

FIGURE 4 | Pathways towards the extended traditional livelihood scenario.

support," "increasing political engagement," "increasing local consumption to resist outside competitors" and "developing local markets." The most important third actions are "pollution reduction" while simultaneously "increasing local consumption to resist outside competitors."

The decision over which action to take is positively influenced by three drivers. (1) "Village development" leads to employment opportunities, transparent government actions, and more education possibilities, (2) "land-use changes" lead to environmental protection, and (3) "changing water management" leads to water conservation. Additionally, according to the actors, improving infrastructures has a strong positive impact on the evolution of traditional livelihoods. It includes the construction of roads, health care and education facilities, real estate, water treatment facilities, and waste disposal. These measures would benefit a more socio-ecologically balanced development.

In the EEA, the villagers engage in small enterprises. The need to shift to this alternative scenario is signaled by declining rainfall, higher levels of water pollution, and unaffordable cost of livelihood inputs. A shift toward the EEA would avoid a situation where fishing and farming products are no longer in demand, the number of customers decreases, and households have less income. The most important actions are "increasing local consumption to resist outside competitors" and "securing access to markets and sales." The feasibility of the EEA depends on receiving and using financial support, e.g., to afford better education or to construct water tanks. As some upcoming enterprises would be dependent on water (e.g., car wash), water would have to be made more accessible. These support mechanisms would raise the standard of living and the viability of small business owners.

The EEA could come into play under all four drivers. (1) "Village development" leads to the creation of employment opportunities, better education, and more transparent government action, (2) "land-use changes" lead to construction activities, including building small-scale commercial infrastructure, (3) "changing water management" leads to new water supply and distribution mechanisms and a greater awareness of water usage, and (4) "urbanization" leads to the adoption of urban lifestyles and population growth, which opens up new consumer markets.

Scenarios Created by the Expert Strand

The experts developed three future livelihood scenarios. The "preferred livelihood scenario" (PLS) aims at diversity consisting of water-based and non-water-based livelihoods, including variations of farming and fishing, craftsmanship, services, tourism, and industries. The first alternative scenario focuses on "water-sensitive farming" (WSF) and the second alternative scenario on "commercial farming and fishing" (CFF) (**Figure 5**).

The experts agreed that "urbanization" has the greatest impact on livelihoods and poses the greatest uncertainties for all scenarios. One expert on periurban planning said: "One of the pressing vulnerabilities has to do with increasing urban development and urbanization with varying levels [...]. Unless you intervene, you are just letting it take shape under immense market pressure, pressure over land, to increase land values and therefore change the use of maybe less lucrative forms of land-use." An expert on periurban agriculture states the effect that urbanization has as "people would be cultivating houses instead of crops." Other drivers are "weak institutional framing," "overexploitation and pressure on resources," "lack of access to education and finances," and "inequality among livelihood groups." Each driver is announced by distinct signals leading to one of the three livelihood scenarios.

There is consensus that the scenarios could be supported by upgrading village infrastructure and by local environmental protection. This support should coincide with strengthening the participatory element in governance. In this way, Paud could be governed through a local, value-based lens that balances the residents' vulnerabilities, resilience, and potentials and creates much stronger social cohesion.

The Preferred Livelihood Scenario (PLS)

The PLS focuses on the full economic potential of the village with different agriculture (farming, dairy, livestock, horticulture, floriculture), fishing, craftsmanship (e.g., pottery), service-oriented (e.g., tourism, small-scale economies), and industrial employment. The PLS was assessed as the most realistic scenario and can be compared to the actor strand BAU. It focuses on multiple livelihood possibilities.

To ensure the PLS's positive effect on livelihoods, certain institutions need to be created. Skills development programs and financial support (e.g., start-up and innovation funding) could support non-water-based livelihoods. Financial support, e.g., for machinery, education, or training to upgrade farming patterns (intensification), could enhance traditional livelihoods. Especially small-scale farmers are dependent on financial support. Traditional livelihoods could further be enhanced through incentives for better product marketing, e.g., through exhibitions and product certification, to extend sales territories and open up new markets.

To empower different livelihood groups, a stronger integration in decision-making processes is needed. Any institutional support can only be established sustainably through a multi-actor governance arrangement, including the *gram panchayat*, the district level government and the state government of Maharashtra in collaboration with existing local associations and informal networks.

The experts identified seven actions for the PLS. The most important actions are "creating inclusive and diverse work fields" (according to season, or gender, rural/urban-orientation, combining traditional and newly emerging occupations) and "modernization" (e.g., via new technology). The second most important actions are "identifying livelihood preferences and available capitals" in a participatory process, "adapting livelihoods to climate variability" (e.g., with environmentally-smart farming practices), and "receiving better education and training." Education and training are important for those upgrading existing livelihoods with new expertise, for those seeking a completely new livelihood and need to acquire new

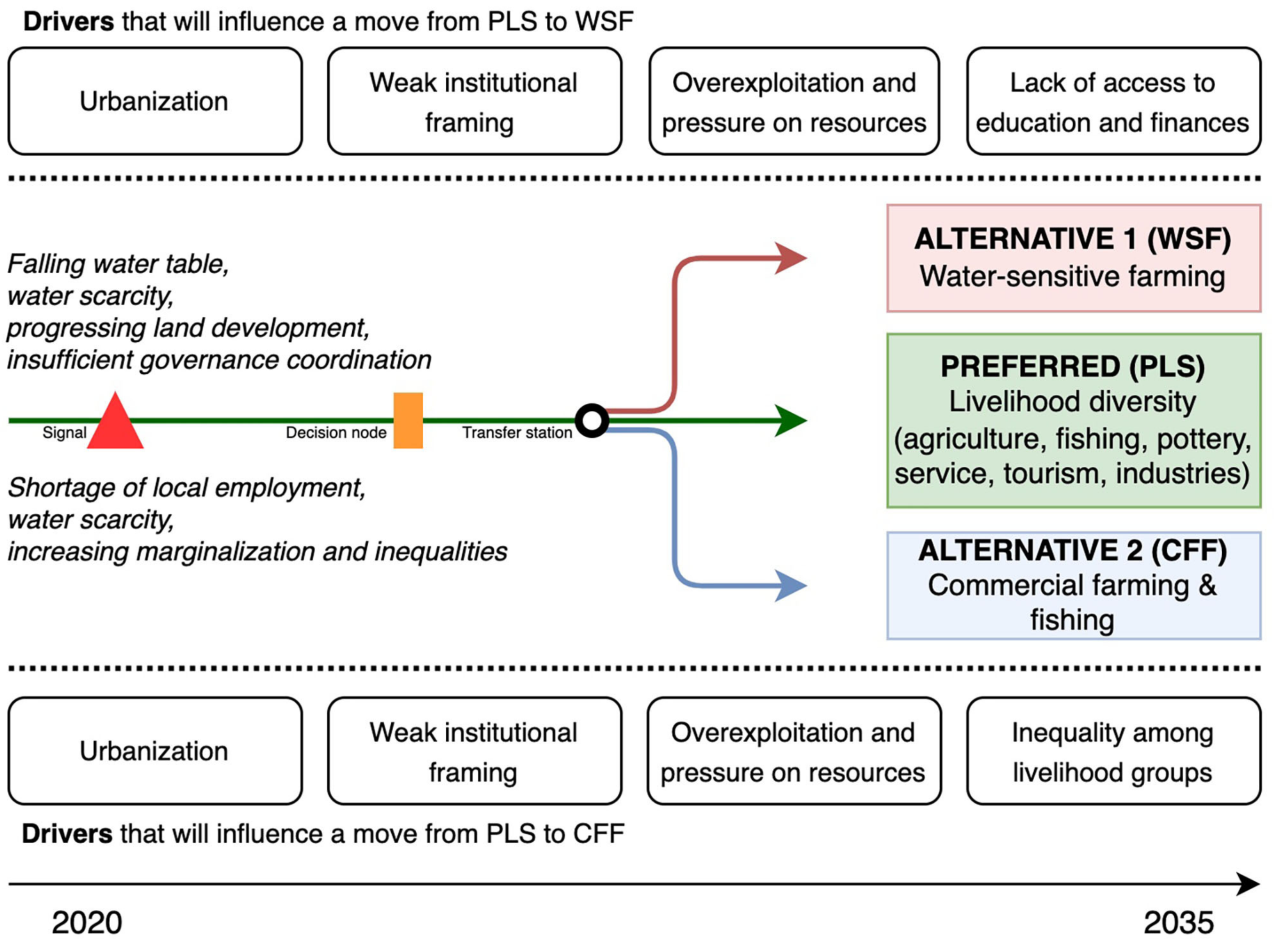

FIGURE 5 | Experts' view on future livelihood scenarios.

skills, and also for those facing higher competition for jobs. The third most important actions are "monitoring change" (e.g., to enable quick adaptation mechanisms), "receiving and using financial support and incentives," as well as "creating village unity and nourishing community sense," "increasing the productivity of livelihoods," and "creating strong rural-urban linkages." The decision over the sequencing of these actions depends on the livelihood group.

The experts expect five specific drivers under which the PLS is not feasible. (1) "Urbanization" leads to livelihoods being more strongly incorporated in Pune's urban dynamics, with Paud facing progressing land development, rising land values, water scarcity, and increasing pollution. It thus may trigger a growing shortage of local employment. (2) "Weak institutional framing" leads to administrative fragmentation and power constellation changes and affects the access to necessary information, e.g., on how to access livelihood-related support systems. It weakens periurban institutions within the larger rural-periurban-urban continuum and may result in unregulated development. Farmers who depend on clearly defined land-use regulation and water distribution are more vulnerable to these uncertainties. (3) "Overexploitation and pressure on resources" lead to depleting water resources and a falling water table. Access to available water resources becomes more costly, and water users are expected to face higher water charges in the future. (4) "Lack of access to education and finances" results in low-level livelihood-related knowhow, e.g., in regard to new cultivation methods. It also makes the shift to other livelihoods more difficult. (5) "Inequality among livelihood groups" means that one livelihood group will dominate over another. An expert on policy and planning explains the expected vulnerabilities arising from inequality: "A likely source of vulnerability would be the sharp differentiation of [livelihood groups] because not every community member will be well equipped [...]; it will depend on their assets. Community differentiation within the village sharpens, the possibility for conflicts will increase and social nets will be affected." Depending on which combination of drivers affects the course of village development more strongly, a shift to one of the two alternative scenarios may be necessary.

The Alternative Livelihood Scenarios

The experts consider the WSF as the most desirable alternative scenario. They consider the location at the edge between the Deccan Plateau and the Western Ghats in the river catchment area advantageous for water-sensitive farming since much of the agricultural land can be irrigated using rain water, especially during the monsoon. An expert on regional development explains: “This entire village should be planned with proper ecological planning, where you define which areas should not be touched at all, which areas can have a kind of development in terms of concretization, which are eco-fragile areas or areas around water. So, ecological land planning should be the basis for this area.” High-density residential development, as is often the case in the periurban, would alter the natural systems and restrict the WSF.

Signals to move to the WSF include hydrosocial dynamics, such as a falling water table, water scarcity and progressing land development as well as insufficient coordination of local governance. This would lead to initiatives failing repeatedly and impeded access to institutions for different livelihood groups. The feasibility of the WSF depends on local farmers’ access to agricultural information, e.g., on the composition of arable land, to understand the possibilities of cropping and water intensities of different varieties.

The CFF focuses on commercializing traditional livelihoods. The proximity to Pune could be a locational advantage. An expert on periurban development elaborates that “Pune is well-known for all kinds of adaptation. [...] There is a growth zone with technology between Mumbai and Pune; it is an agricultural belt, so it has completely changed in terms of [...] value addition of agriculture.” The shift toward the CFF is signaled by a growing shortage of local employment opportunities, water scarcity, increasing marginalization and inequalities. These signals point to unbalanced, urban-dominated development and a loss of rural identity, leading to the disappearance of agrarian systems.

One option to commercialize farming livelihoods is to upgrade to dairy farming. One expert with a background in geography describes: “It can be another way that they can have [...] rather than having water intensive crops.” Another strategy is to move toward horticulture and floriculture. These livelihoods are less land and water-intensive than traditional farming and can produce for specific markets. According to one expert with a background on geography, “farmers can be taken off the hook of doing traditional farming but go for this concept of intensive farming.” However, as the initial investment for hydraulic infrastructure and technical equipment is comparatively high, smallholders need government support for this transition.

Figure 6 displays the experts’ responses in a line sequence of up to three actions from left to right toward the WSF and CFF. For instance, in the WSF, expert 1 envisions “adapting livelihoods to climate change” as a first action, “cyclical water usage” as second action and “water saving during irrigation” as third action. In the WSF, the most important first action is “water quality and resource trend analysis and monitoring.” The most important second action is “receiving education and trainings.” The most important third actions are “receiving education and trainings” and simultaneously “generating income and creating rising land values.” In the CFF, the most important first actions are “identifying livelihood preferences and capitals” and “building cold storages.” The most important second actions are “introducing new varieties” and “building cold storages.” The most important third actions are “modernization” and simultaneously “introducing new varieties”. Actions important in both scenarios include “modernization,” “valorizing and promoting local produce and products,” “generating higher incomes and land values,” and “identifying livelihood preferences and available capitals.” Some actions, e.g., “receiving and using financial support” or “receiving better education and training,” are only feasible with adequate institutionalization, e.g., through banking systems, or a sufficient educational environment.

DISCUSSION

The actor strand BAU and expert strand PLS show similarities but, in light of the expected hydrosocial dynamics, develop different alternative pathways. The results indicate the crucial role farming plays in the foreseeable future and the high relevance farmers can take in shaping local waterscapes. But what is the significance of the individual drivers, actions, and institutions from an expert and local perspective, and how can local communities interpret the scenarios for their own good?

Drivers of Hydrosocial Uncertainty

Figures 3, **5** show that periurban livelihoods are expected to be influenced by different drivers. These drivers generate new possibilities for decision-making of local communities, but moreover they result in hydrosocial uncertainties for the famers. As the drivers are mostly interdependent, the uncertainty for farmers increases in complexity. The three-stage approach of scenario-based planning we followed allowed the drivers to be iteratively related to the scenarios and to be correlated with the constitutive actions and institutions.

Actors and experts consider the driver “land-use changes” to cause the greatest uncertainties. It might bring with it negative and positive transformations. On the downside, and in accordance with Mitra and Banerji’s (2018) investigations in periurban Kolkata, and Curmi et al.’s Curmi et al. (2014) assessment on a broader global scale, we can see how land-use changes can irreversibly damage the resource base and increase the risk of overexploitation in Paud. In parallel with urban sprawl, they result in land encroachment and enable construction activities. The institutions that should govern such periurban land-use changes are often not well-equipped and act within weak institutional frameworks. These unregulated hydrosocial pressures tempt farmers to find new livelihoods or relocate. On the positive side, land-use changes can include schemes for better environmental protection and promote pollutant-free ecosystems to the benefit of farmers’ produce. Nevertheless, both

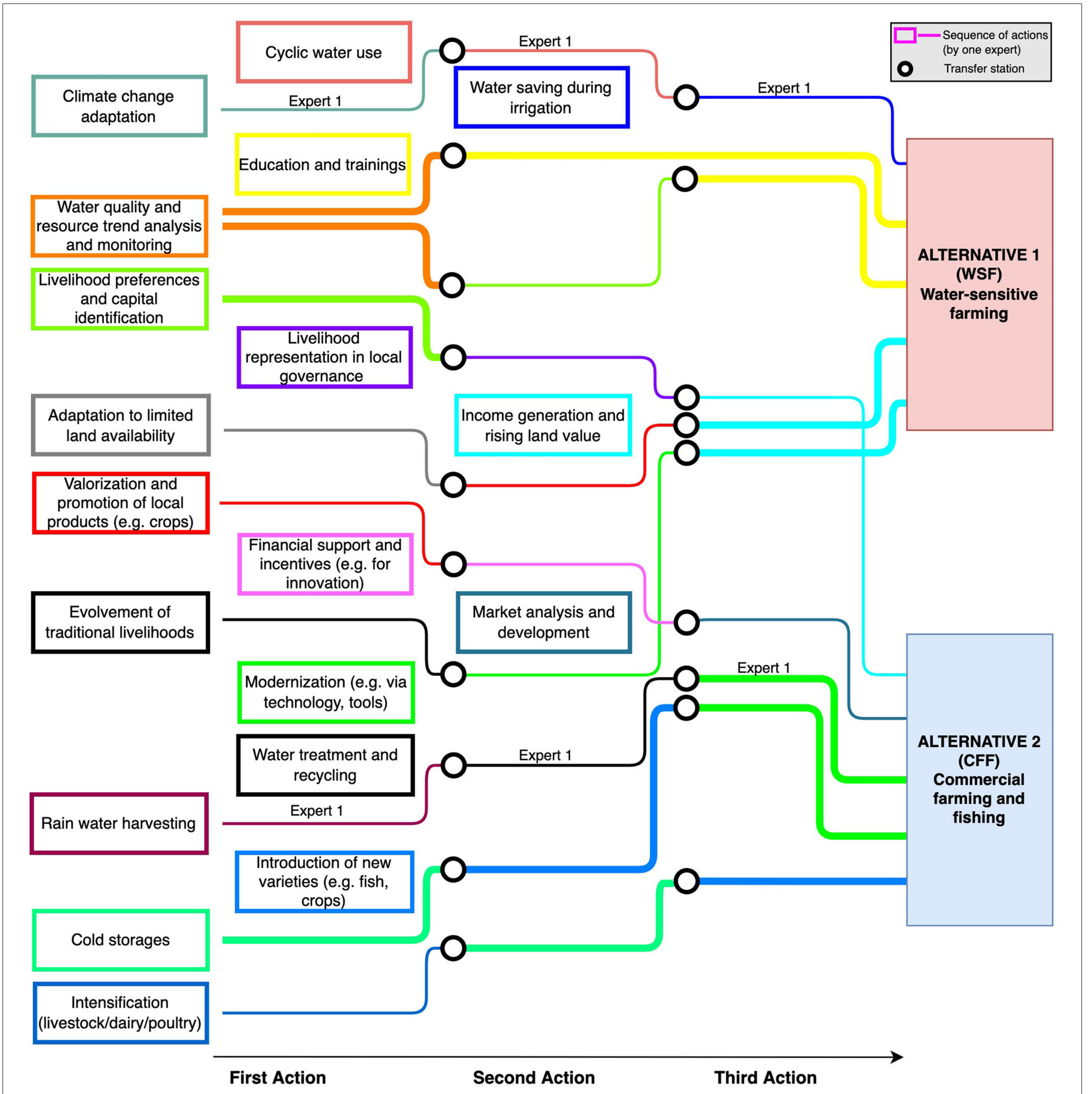

FIGURE 6 | Pathways towards the experts' alternative livelihood scenarios.

negative and positive implications of land-use changes might introduce long-term changes.

"Changing water management" affects water quality and quantity and drives hydrosocial alterations. Thus, these changes need to be coordinated (Hui and Wescoat, 2019). In accordance with what Follmann et al. (2021) have reviewed for periurban areas in the Global South, we find that changing water management coincides with the driver "inequality among different livelihood groups" in Paud. Better-off farmers are enabled to accumulate more water and use it more intensively. Marginal farmers' cost-benefits-ratios' are interrupted, leaving them with relative water scarcity. Many of these farmers withdraw from farming in favor of other employment.

"Overexploitation and pressure on resources" is exerted in response to these inequalities. In Paud, water access is not formally regulated and depends on individual capitalization and location. Those denied access often create their own hydraulic infrastructure. These private means of water appropriation in turn contribute to unsustainable water drawing. The driver "weak institutional framing" enhances the water distribution challenge in the periurban due to administrational fragmentations and unclear responsibilities (Thomas et al., 2017; Hui and Wescoat, 2019). This weak institutionalization may even allow local farmers to co-design new means of water management. To combat this development, the participatory element in government would require strengthening.

"Weak institutional framing" also influences rural-periurban-urban water dynamics (Thomas et al., 2017; Punjabi and Johnson, 2018). In connection with the driver "lack of access to education and finances," it could increase the rural-urban divide. This increase is mirrored through only a small group of periurban farmers with a specific orientation beyond the local scope being able to benefit from the advantages of both locations. Rurally embedded, smaller-scale farmers are often denied access to education and finances and excluded from skills development (e.g., to learn about new farming methods) and are unable to upgrade their hydraulic means (Butsch and Heinkel, 2020). In Paud, these disadvantages result in a lack of agency. These farmers are not able to actively shape local decision-making or determine their own development. Farmers who increased their product range toward urban consumer markets often have better access to relevant institutions and are thus at an advantage.

"Village development" implies opportunities and challenges for farmers in Paud. Positive implications are better educational systems on the village level, active communal integration, and opportunities for farmers to modernize. Village development benefits how traditional farming evolves, strengthens the peasant community, and counteracts the superiority of other livelihood groups. In a socially sustainable way, village development thus reduces the negative impact of other drivers. Yet, negative implications of village development could aggravate complexities in the periurban and lead to a greater intransparency, which again increases farmers' exposure to uncertainties.

Actors and experts consider "urbanization" to have the greatest impact on periurban farming livelihoods as it shows strong intersections with the other drivers (Srinivasan et al., 2010; Díaz-Caravantes, 2012; Vij and Narain, 2016). In Paud, urbanization already contributes to land-use changes by triggering a strong migration influx. This affects the socio-cultural fabric and increases marginalization. It further increases exposure to industrial produced pollution, which degrades the quality and quantity of water. However, at the same time, urbanization may create new occupational perspectives for farmers who want to leave farming.

Complementing Local and Expert Knowledge for Adaptive Decision-Making

The multidimensionality of periurban futures (Butsch and Heinkel, 2020; Follmann et al., 2021) is reflected in the scenarios' heterogeneity. Building on Giaoutzi et al.'s (2012) findings that scenarios are crucial in participatory planning, we argue for their extension and supportiveness as forecasting tools to enhance farmers' capacities. But, how can farmers benefit from the local-expert-knowledge transfer (Carolan, 2006) and apply different types of knowledge to shape their futures? And how does that knowledge support their ability to make adaptive decisions?

Figures 4, **6** show that major hydrological changes are anticipated, resulting in water scarcity. These changes will lead to decision-making processes being set in motion. However, all six scenarios also show the high future relevance of farming, despite the knowledge strands' different starting points. The actors approach future thinking from individual perspectives, address challenges, and generate a picture of the status quo in the village. The cumulative results reveal trends in hydrosocial uncertainties. The actor knowledge displays more short-term vision on how to develop existing potentials under changing hydrosocial conditions. As in other periurban settings (Thomas et al., 2017), actors in Paud state that they would predominantly rely on official support from multiple governance entities.

The experts depict abstract anticipations with a stronger focus on normative future predictions than on the current conditions. They emphasize the role of institutions and how hydrosocial power geometries could be balanced. Expert knowledge suggests not a complete change of existing agricultural structures but assesses the requirements and possibilities of restructuring them by activating existing potentials. Combining both knowledge pools could enhance adaptive planning processes toward a more sustainable periurban future (Hermans et al., 2017; Haasnoot et al., 2018) and strengthen farmers' capabilities for planning in the long term. The negative impact of events beyond their influence could thus be reduced.

The experts' PLS mirrors what actors consider in the BAU. There, livelihood diversity is initially viewed as diversity at the village level and subsequently takes on additional nuances. Agriculture can be developed into different types of farming. The experts consider livelihood diversity as freedom of choice, with more self-determination than generational predetermination. The anticipated future livelihoods in the PLS reflect the impact of the expected drivers ("urbanization," "village development"). These drivers may prevent the continuation of established occupations. But they could stimulate rethinking toward more diverse alternative possibilities, leading to traditional livelihoods taking on multiple new forms. Based on these considerations, the experts visualize more possibilities for the village economy and thus more actions and institutions. From the actors' perspective, livelihood diversity means household specific diversification as means of improving livelihood security. They anticipate familiar livelihood profiles that do not require specific training. There are two reasons for this: (1) The strong belief that work is inherited intergenerationally and the village structure makes external institutions for learning new skills less relevant. (2) Traditional livelihoods are subject to strong social attribution. Actors could expand new capacities by drawing potential from both ways of thinking.

Examining the experts' PLS and the actors' BAU, we found similarity in the reported drivers (e.g., "urbanization"), institutions, and actions, such as creating inclusiveness, diverse work fields and livelihood equality or developing adaptation mechanisms. Yet, actors approach adaptation through experienced restrictions to water or land whereas experts consider that change monitoring and adapting, e.g., to climatic variability, is important. We argue that complementing both approaches could enhance knowledge transfer (Carolan, 2006) and help to build targeted strategies (Versteeg et al., 2021).

The alternative scenarios present more differentiated means for adaptive decision-making and clearly state the signals and drivers and their opportunities and challenges. Both strands reference mitigation as a response to the drivers. In contrast to other case studies, where local farmers adapt through changing cropping patterns or using waste water (Thomas et al., 2017), local knowledge in Paud suggests counteracting "urbanization" and "land-use changes" by resisting outside competition, securing local resources, and opposing hydrosocial power imbalances through greater participation in local governance. The experts, in turn, suggest valorizing local products and identifying livelihood preferences to encourage a strong village profile, especially for more vulnerable farmers, and additionally securing livelihood equality as a contribution to the evolvement of farmer agency.

The strands differ in two aspects. (1) There are differences in the variety of actions and institutions. Reflecting the uncertainties that periurban farmers are exposed to, experts generate multiple sequencing possibilities for actively shaping the local hydrosocial cycle. Actors consider that local scope for action is actually more restricted in practice than in theory. For them, the prevailing hydrosocial uncertainties determine a frame in which farmers are acting and the sequenced actions are limited. (2) There are differences in the level of abstraction. Where local knowledge generates superordinate actions, e.g., pollution reduction, expert knowledge suggests the corresponding specific actions, e.g., water treatment or quality monitoring. Where local knowledge focuses on higher level institutions, e.g., financial support, expert knowledge expresses what to invest it on. With these specific actions, expert knowledge paints a precise picture of how and why hydrosocial patterns may evolve. These actor-expert discrepancies could stem from periurban complexities and the contextual, application-oriented actors' knowledge, which is distinct from the technical knowledge of external experts (Agrawal, 1995; Beckford and Barker, 2007). Yet, methodological differences and the digital approach could also be responsible for the two strands being divergent.

Framing farming livelihoods within the political ecology perspective (Thomas et al., 2017) shows how adaptive decision-making can function as a crucial means for farmers' livelihood evolvement. With every new action and institutional change, the hydrosocial fabric in which farmers operate is altered. The scenarios can be used complementarily to support farmers in shaping their futures through flexible short- and long-term decision-making. We thus argue that translating these complex frameworks into practice could initiate a differentiated approach for farmers' future adaptive decision-making.

Methodological Reflection

This research demonstrates how a modified Delphi method, overcoming the expert-oriented focus (Perveen et al., 2017), can successfully integrate local and expert knowledge and shows how to digitally circumvent personal face-to-face contact (Taylor and Ryder, 2003; Day and Bobeva, 2005). But can farmers actually be reached through this kind of approach and use frameworks like these to support their decision-making? Throughout the process of building scenarios, four perspectives emerged:

(1) Due to the generation divide, many active farmers are not amenable to change and developing adaptive capacities. The successors of farming households, who could initiate a transformation of hydrosocial farming patterns and would benefit from these scenarios, no longer see their future in agriculture. For this successor group, only the diverse livelihood scenario would be appropriate.

(2) Social status (Vij and Narain, 2016) prevents many livelihood groups from deciding on new employment prospects. Socially and financially strong farmers, for instance, see their future in only that livelihood. For them, only a highly restricted livelihood scenario would be suitable. On the other end of the continuum, marginal farmers are often denied access to institutions and are incapable of accumulating capital to activate their potential. These consolidated societal structures create vulnerabilities and specific resilience (Maru et al., 2014).

(3) Both strands agree that the translation of complementarily generated knowledge from theory into practice depends crucially on an active local embedding:

"Active political environment is necessary while talking with the community and [...] planning the best future. These necessary steps should be taken to form an ideal future. People should be involved and ask the *gram panchayat* actively what the plans are for the future" (Poultry farmer from Paud).

"Because of the huge diversity, complexity and heterogeneity of these places, what you really need is a really strong local presence of an organization familiar with the local context, that is somewhat embedded there, that can mobilize communities [...] and get them into dialogue with state agencies. More of those approaches are needed in the periurban areas" (Expert on periurban water management).

Due to the timing of our research in the midst of the COVID-19 pandemic, only a small section of Paud's society could be included in the study. With extended research, local knowledge, e.g., from landless and marginal farmers, could have been included, as demanded in the literature (Smith, 2011). Further research could also involve local government units. In this process, knowledge exchange between actors and experts could be enhanced (Moyo, 2009; Oliver et al., 2012) for more balanced adaptive decision-making processes.

(4) Long-term planning is challenged by hydrosocial dynamics being constantly in flux, altering adaptive capacities and coping mechanisms of periurban livelihood groups and their mutual influence. Our research contributes to understanding the hydrosocial positioning of farming livelihoods in the dynamic nexus between society and water (Butsch and Heinkel, 2020; Butsch et al., 2021). However, to capture fast-changing capacities and long-time variances, the methodology must be implemented over a longer time (Versteeg et al., 2021).

CONCLUSION

This study investigates possible ways for farmers to plan for future hydrosocial uncertainties. We adopted the concept of the hydrosocial cycle grounded in political ecology as analytical perspective to understand the production of these uncertainties. Using a modified Delphi method with actors and Indian and international experts, we complemented the hydrosocial lens with a scenario-based planning approach to demonstrate the possibilities of activating local capacities and supporting adaptive local decision-making accordingly, and showed how this approach could inform future governance. We showed how hydrosocial uncertainties are perceived and how local agency can impact the hydrosocial cycle. Yet, as we combined two knowledge systems with distinct perspectives on periurban futures, we could contrast different mechanisms for future thinking: Short-term vs. long-term, detailed vs. abstract, practical vs. theoretical, and impact-oriented vs. capacity-oriented.

We identified three livelihood scenarios for each knowledge system. They revealed how farming will continue to play a significant role in Paud, how farmers crucially shape the hydrosocial dynamics, and how an institutional framework could work as a support system for farmers. Local actors and experts identified eight different drivers that impact the scenarios. "Urbanization" is expected to impact livelihoods most and may alter the hydrosocial cycle in the long term. However, all drivers intersect and collectively produce complex, hydrosocial uncertainties for farmers.

From a theoretical perspective, our results can contribute to the field of political ecology in four ways: (i) they confirm the suitability of the political ecological approach to identify and analyze complex problems of periurban transformation processes, which are often shaped by unequal power relations; (ii) they demonstrate that these problems can be made visible through customized participatory methods; (iii) in doing so, they refine perceptions of drivers of change and their impacts on socio-ecological systems, and thus have the potential to inform future analyses of periurban transformations, rooted in political ecology; (iv) taking political ecology's critical analysis further, our approach provides an avenue for including potentially disempowered groups in future making, thus contributing to means of overcoming political ecology's weakness in influencing policies.

To enhance adaptive decision-making, we further argue that periurban communities could benefit from complementing local and expert knowledge, activate and expand existing potentials and simultaneously initiate higher-degree participation in local governance. However, both knowledge strands considered the integration of co-produced knowledge into local governance action as challenging. To illustrate the dynamic periurban water-society realities, our method could be enhanced through including more diverse periurban stakeholders, monitoring and addressing fast-changing dynamics over a longer period on the local level, and through generating more inclusive and transferable knowledge during interactions with experts. Scenario-based planning for spaces under hydrosocial uncertainty could then become an intervention framework for local planners and policy makers to facilitate long-term transformation.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article can be made available by the authors after all research analyses from the project are published or when consent to make the data accessible is given by all consortium partners of the H2OT2S project. Before sharing personal information will be anonymized avoiding the risk of compromising the interests or even safety of individuals or groups.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their informed consent to participate in this study orally, which was recorded by the interviewers.

AUTHOR CONTRIBUTIONS

This article was conceptualized and written by SL with supervision, contributions and editing by CB. The methodology was jointly developed by SL, SG, SC, LH, and CB. The data collection was conducted by SL, SG, and SC and supported by CB and LH. The analysis was led by SL with contributions from SG, SC, LH, and CB. All authors contributed to the article and approved the submitted version.

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