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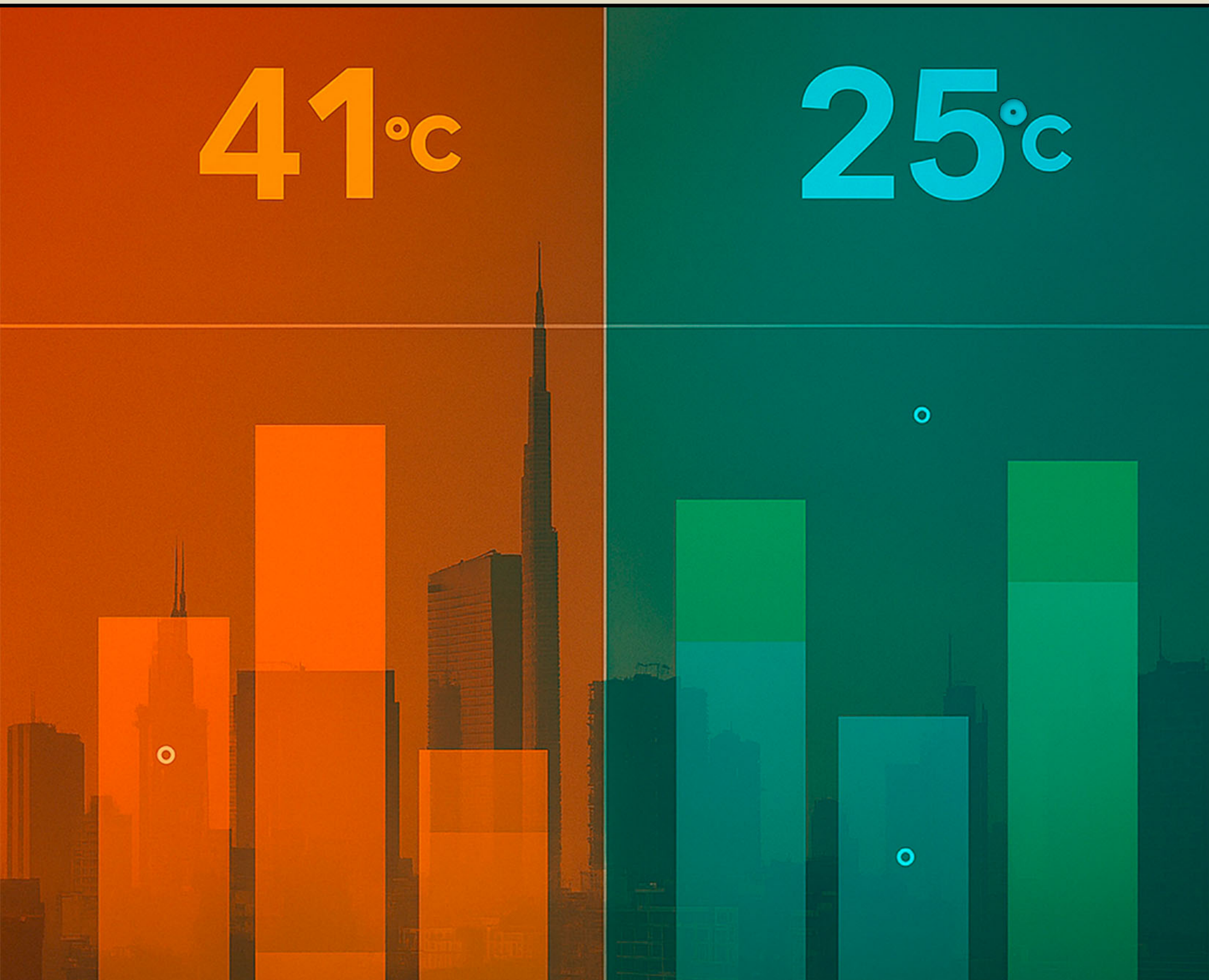

NEW CHALLENGES FOR XXI CENTURY CITIES

Multilevel scientific approach to impacts of global warming on urban areas, energy transition, optimisation of land use and emergency scenario

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Risk as a wicked problem in planning: the role of future non-knowledge

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Abstract

Dealing with spatial organization, planning and design has to cope with something that is not (not yet or never will be) there. This is a matter of knowledge and of knowledge management, a matter for times to come: so in knowledge management the facet of non-knowledge appears. The research reflections proposed here are connected with activities carried out in the case study of Biccari, a small village in the north of Puglia (Italy), located on the slopes of the Dauni Mountains, between the Apulian plateau and fragile mountain terrains. It involved the University of Sannio and the Polytechnic University of Bari, to provide scientific support aimed at drawing up the town's master plan (PUG). The territory is affected by an extensive paleolandslide, creating significant hydrogeological risk conditions. Despite this, the local community tends to remove such risk from their perception, showing fatalistic attitudes toward phenomena considered inevitable. The paper explores how to deal with "non-knowledge" in spatial planning, particularly by integrating local risk perceptions and decision-making dynamics into agent-based simulation models developed using NetLogo software. As an exploratory study, it proposes a prototype framework to simulate interactions between institutional decisions, environmental dynamics and community behaviors, with the goal of supporting more adaptive, informed and resilient planning strategies – managing uncertainty as a constitutive element of planning in fragile territories, rather than as a problem to be eliminated.

Keywords

Planning, Future, Non-knowledge, Uncertainty, Risk, Fatalism

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1. Introduction

Planners and decision-makers face the complexity of spatial and environmental decisions all the time. In recent decades there has been a high degree of uncertainty and rapid environmental changes. It required policy-making and planning approaches useful for making effective, robust and resilient or antifragile choices with a final far sighted look at the environment as a system (Taleb, 2012; Buurman & Babovic, 2016). In our discipline field the consciousness of the necessity to deal with the future arose in a few decades with a flourishing of methods and reflections. They dealt with future workshops, building scenarios, back chain mirror strategies (Jungk & Mullert, 1996) that dialogue by constantly investigating the future even though not all the developers of the research in this field has worked in this direction.

As human beings we are immersed in the eternal present that changes moment by moment, and we are also constantly projected towards a tense future (which we can imagine on a continuous line that goes from the infinitely close to the infinitely remote). This is a matter of daily living. Reality is full of hints that appear as unrelated and subtle, they are in a chain of causes instead in space and time that often are not read in a systematic and coherent perspective (Gumbrecht, 2014). This has been sadly and problematically true, e.g., about the climate change issue and the last pandemic. A part of the literature, both scientific and informational, had tried to argue and speculate about such topics, in order to forward the message to the communities and decision makers: it was a reading of a feared future toward the forecasting of a future to be averted.

Dealing with spatial organization, planning, design has to cope with something that is not (not yet or never will be) there. This is a matter of knowledge and of knowledge management, a matter for times to come: so in knowledge management the facet of non-knowledge appears (Stufano Melone & Camarda, 2022).

We have dealt with an interesting case study in a small town in Southern Italy (Apulia region) that could be, in its smallness, a paradigmatic sample. There, a mountain is crumbling but people still want to build there: why?

The case study mentioned above is Biccari, a town of around 3000 inhabitants on the slopes of the Dauni Mountains. The drafting of the new master plan has been engaging the Polytechnic University of Bari group since 2018. A rather long time for such a low-populated centre, only partly due to the problems induced by the recent years of pandemic. A significant problem is the request for expansion of areas to be developed economically, despite widespread and significant hydrogeological problems. The territory is in fact largely affected by phenomena of ancient and slow landslides and hydraulic infiltration which make the soil fragile and prone to extensive cracking. The risk to the safety of people and buildings is significant and the hydrological basin authority has placed strong restrictions on soil transformations. These constraints are enforced until consolidation works are set up - which however are expensive and await appropriate public funding. Yet the Biccari community insists on finding ways to rapidly develop its territory, even in fragile areas, aspiring to immediate socioeconomic improvements. Curiously, a large part of the community tends to consider the indications of the hydrological authorities exaggerated, if not false. They don't believe in the risk, they think that these are slow phenomena that have always been present in Biccari and that cannot be used to block development.

In the above context, the paper aims to explore how to deal with "non-knowledge" in spatial planning, particularly in relation to risk management within contexts marked by uncertainty and environmental fragility. Using the case study of Biccari, the research tries to investigate how local risk perceptions and decision-making dynamics can be integrated into agent-based simulation models, with the goal of supporting more adaptive, informed, and resilient planning strategies over the long term.

It must be said that this work is explicitly positioned as an exploratory and preliminary study, aiming to investigate conceptual tools and modelling frameworks for addressing spatial planning under conditions of epistemic uncertainty and community-based fatalism. This paper builds on our previous research into non-knowledge for planning in this journal (Stufano Melone & Camarda, 2022) by applying and testing those concepts within a concrete case study of environmental risk and community perception. Rather than delivering a fully validated or predictive model, we propose a prototype framework – grounded in real-world complexity but intentionally simplified – to open a discussion on alternative planning logics in fragile territories.

After the present introduction, in Chapter 2 we suggest slightly wider reflections about non-knowledge and future in planning in the broader research field about uncertainty. Chapter 3 examines the case study of Biccari, the above cited small municipality in northern Apulia, particularly dealing with its geomorphological criticalities between the Apulian plateau and the fragile slopes of the Daunia mountains. Chapter 4 develops a reflection on a methodological approach to integrate fatalistic and precautionary agents' positions toward a risky situation, also using a simple simulation model based on NetLogo software. Finally, chapter five reports brief conclusion remarks and possible follow-ups.

2. Dilemmas in planning: the consciousness of a non-knowing the future

Humans project themselves along a linear path that moves through time - the future appears as an open horizon of possibilities to which humans tend from the possibilities offered by the future itself (Gumbrecht, 2014). It is made up of uncertainties, ambiguities, deep unknowns that fatally affect the results of a strategic plan or, more generally, the effectiveness of environmental and design choices.

Furthermore, the relationship between knowledge, non-knowledge, and digitality is a complex one, not fully explored (Monnin, 2018), in an environment of smart cities, sensors, STS, AI support, urban digital twins and so on, a tumultuous growth of tools and devices to be supported with new consciousness about reality and intentions (the purpose for a desired future) (Bencardino & Greco, 2014).

Our reflections concern non-knowledge, and its possible management perspectives in the face of spatial, urban, regional and environmental planning actions, in a constant arrow that looks at the future, searches in the future, and in some sense tries to build a future. But at the same time in our research we intend to fill a quest, about the future of the planning activities for the city, for the territory and extensively for the environment itself, working on methods and theories more and more inclusive, extensive, iterative, adaptive, robust (Marchau et al., 2019).

Unknowing is often not considered negative but is deemed a constitutive condition of knowledge (Wulf, 2018) and at the same time is a challenging opportunity for new ways of being, of staying, of planning and designing objects, the environment we intend to live in, ourselves and our self-future too.

To go back to our field of reflection and application, planning for cities and territories contains normative elements and seeks to control spatial development with social implications (Schubert, 2019). A paradox of planning and non-planning arises, and the interdependence of chaos and order becomes an integral component of planning and of the debate on the future (Schubert, 2019). Planning procedures often are vague and too generally fulfilled with ambiguities and developed over such a length of time that makes them an answer of the past for a future already present.

How to plan resilient and sustainable cities in the long-run? Or would non-planning and the abandoning of cities to market forces and private developers generate the best solutions? (Schubert, 2019).

We see two possible paths to follow, among others. An imaginative path builds scenarios for either desirable or undesirable aims, integrating the largest possible number of hints and intuitions - even the less 'interesting' ones. Another path follows the 'apparently' do-nothing option, building a scenario for future planning where the decision and 'use' are freed from profit, in a sight of a highest common good. The idea, leaning trough a happy degrowth, is using all the new tools, and devices, and consciousnesses in a reflexive and differently constructive way: observing the natural movements of nature and acting only to prevent pre-sighted risks.

For the study of the future, the construction of scenarios, future workshops, strategies, planning actions, the representation of knowledge (and non-knowledge), the role of metaphor cannot be ignored. It is useful also in the organization of memories to be launched -renewed- toward the future, in a form of anterior future or memory of the future, also in the construction of the questions that are asked about the future, in a form of a blind built scenario (Brandimonte, 2004).

These dilemmas of planning under uncertainty are acutely visible in the field of risk governance. Contemporary international debates increasingly move beyond technical risk assessments to focus on the social processes of risk perception, communication, and decision-making (e.g., Renn, 2008; Aven & Renn, 2010). This shift emphasizes adaptive and participatory governance models that can accommodate deep uncertainty and conflicting stakeholder values, much like the "wicked problems" paradigm (Rittel & Webber, 1973). The case of Biccari, with its tension between hydrological authorities and a fatalistic community, exemplifies this governance challenge. It highlights the gap between technical risk calculations and local risk acceptance, a central theme in modern risk governance literature.

3. Paths to overcome the dilemma: introducing a case study

Biccari exemplifies a constellation of factors that make it particularly relevant for exploring the dilemmas of planning under conditions of non-knowledge and environmental uncertainty; it serves as a paradigmatic example in relation to the theoretical framework outlined. Biccari is a municipality in northern Puglia with 2.720 inhabitants, located on a hill in the Daunia mountains at 450 meters above sea level. The municipality develops across a large and variegated territory that includes Mount Cornacchia, the highest peak in Puglia, along with the sources of the Vulgano torrent and Lake Pescara.

Biccari represents a widespread typology of marginal, environmentally fragile territories in Mediterranean mountain contexts and embodies the socio-spatial dynamics of depopulation, economic restructuring, and resource rediscovery that characterize many inland areas. The case encapsulates the drama of demographic decline while simultaneously revealing the tension, intelligence, and environmental sensitivity of its inhabitants in their determination to ensure the survival of their territorial system, coupled with a failure to perceive the intrinsic and 'silent' risk of situations such as the paleolandslide. This duality makes the case particularly instructive, as findings are potentially transferable to similar contexts facing analogous challenges.

The coexistence of significant natural resources – such as Lake Pescara and naturalistic areas with tourism potential – alongside major environmental risks creates a condition of radical uncertainty emblematic of the "consciousness of not knowing the future." The extensive paleolandslide affecting both residential and recreational areas represents the most striking dimension of this complexity, yet what emerged most clearly during participatory activities was a systematic "removal" of hydrogeological risk from community visions despite its objective significance. This cognitive-cultural dimension – the gap between expert knowledge and local perception – makes Biccari particularly suitable for exploring how collective belief systems interact with technical assessments in shaping planning futures, a central concern in contemporary debates on risk governance and participatory planning.

The paradigmatic complexity of this small inland center is further enriched by the energy dimension characterizing its subsoil. Beyond the presence of wind turbines already present, investigations have been conducted on underground gas resources as potential sources of renewable energy. This stratification of energy potentials adds another layer to the intricate tapestry of opportunities and constraints that planning processes must navigate.

The institutional context further contributes to this paradigmatic quality. The regulatory rigidity and implementation delays characteristic of Italian planning systems have resulted in environmental constraints producing stasis rather than adaptive management. Legal orders blocking possible transformations, established following the identification of the paleolandslide, left planning activity formally unupdated while awaiting consolidation works significantly behind schedule. The Biccari administration's request to explore dynamic, behavior-based regulations that could adapt normatively to the landslide's behavioral dynamics represents an innovative yet challenging attempt to overcome deterministic planning paradigms.

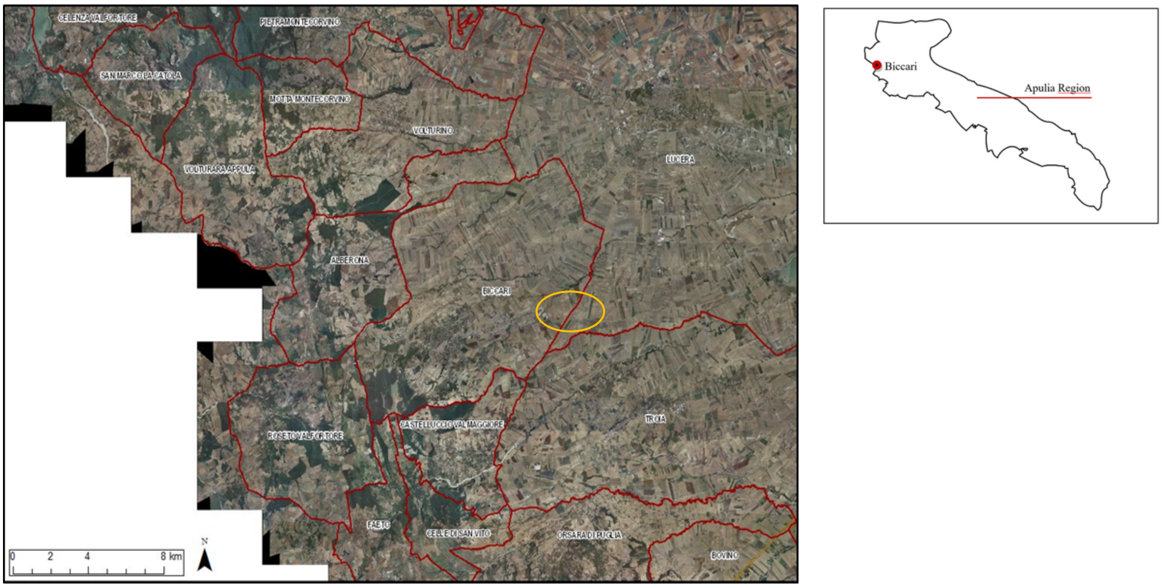

Fig.1 Biccari between Capitanata and Monti Dauni (from S.I.T. Puglia – orthophoto 2016)

The municipality concentrates environmental fragility alongside resource potential, socio-economic marginality alongside community resilience, cultural fatalism regarding the 'invisible' paleolandslide alongside environmental awareness regarding renewable energy possibilities, institutional rigidity alongside administrative innovation, and knowledge multiplicity emerging from participatory processes. The inhabitants' failure to fully grasp all the nuances of inherent territorial risks – particularly the paleolandslide's implications – while simultaneously demonstrating sophisticated understanding of the territory's potential for sustainable tourism and renewable energy development, exemplifies the misalignments between place perception, community aspirations, territorial risks, and regulatory frameworks that characterize contemporary planning dilemmas.

These characteristics converge to outline reflections that are, in a sense, 'prêt-à-porter' – ready to be engaged with and adapted to confront realities that may be either more simplified or more complex, yet sharing fundamental dilemmas of uncertainty and misalignment. The availability of rich qualitative data from participation processes – visions, narratives, local discourses – combined with the technical complexity of modeling landslide dynamics and risk perception creates an ideal testbed for the multi-agent approach proposed in this research. Biccari thus becomes not merely a case study but a microcosm concentrating the theoretical and practical challenges that demand serious reflection within both scientific approaches and the applicative pathways of planning processes.

The vision of the master plan is interpreted in an intrinsically operational sense and is built with a strategic and inclusive approach, structurally based on the collection and exchange of multi-agent knowledge (Borri et al., 2014; Camarda et al., 2020). The regulatory framework of the Puglia Region requires a set of administrative and planning acts aimed at defining an optimal structure of the regional territory, to be prefigured and regulated through regional territorial planning, as well as through guidelines that must be compatible with the plan. Since the 1960s, the small municipality of Biccari has been affected by the phenomenon of depopulation of the mountain anthropic system, in a period in which political pressure and economic attention had focused on the implementation of large industrial systems. It was a period in which in a context like that of the small town there seemed to be no possibilities and resources. Today there is still a generalized economic crisis but there is also a new awareness of the immense naturalistic and geomorphological resources as well as the traditional richness of these places. This is where the community wanted to restart, and this is where scientific support for the PUG got involved.

Within the participation activities for the collection of 'local' knowledge useful for the construction of the new Biccari plan, participants were asked to tell how they imagine their country in the near future, asking for a long-term 'vision' effort term. But few of the descriptions collected can truly be defined as visions, the answers are mostly requests or claims that derive directly from the desire to resolve the perceived and experienced critical issues. The future Biccari is mostly imagined as a town with a tourist and agricultural vocation thanks to the valorisation of the historic center and the naturalistic areas, hypothesizing the possibility of a commercial focus on crafts and typical local food products. The historic center and the rural/landscape/agricultural areas are imagined as dotted with activities that thrive on tourism managed in a sustainable and responsible manner. Together with the hope for what is defined as the 'care of the walls', i.e. the request for physical regeneration, we have noted the focus on the desire for specific attention to social aspects with respect to all age and income groups.

The cooperative knowledge construction phase made it possible to collect a series of data, indications, suggestions, and ideas of remarkable interest to fuel the start of the planning process. The result of the participation activity lends itself to some detailed preliminary readings, as well as to the production of reflections also in operational terms (Stufano Melone & Rabino, 2014). A summary of the possible interpretations that may emerge from this reading exercise is reported below, with the aim of providing a first framework from which it is possible to define further reflections, amendments and additions, as well as definitions more oriented and focused on the purposes of the planning process. Our administrative and legislative system is made up of superordinate administrations, so political decisions have an extremely important impact on individual and collective life and on the individual and collective management and use of the territory.

After the crisis induced by the Covid-19 infection, the previous regulatory forms further revealed the planning crisis and how the intrinsic management intentions were aimed at specific programmatic categories and were often separated from the true needs of urban centers or naturalistic areas, of ecosystems, of resources. This today can be interpreted and indeed expressed thanks to a greater awareness of the complexity of the system in which we are immersed. One can clearly read in the visions the distance between the policies and choices made in the past as a form of dyscrasia in the scalarity from large to small, from the collective to the individual, from the anthropocentric to the non-anthropocentric.

What curiously emerges from the consultation is an insurgent removal, from the set of other critical issues identified, of the hydrogeological risk triggered by the paleolandslide downstream of Lake Pescara. The data from the paleolandslide, which constitute such an impactful aspect yet left out of the population's narrative, have triggered a series of reflections on this 'removal' and the possible approaches to 'reconcile' and 'stitch' visions, current reality and perspectives, so as to be as integrated as possible.

4. Notes for an integrate approach in dealing with risks

In the case of Biccari, in fact, a rather particular and for various reasons complex problem arises. The question concerns the presence of an extensive paleolandslide that originates at the peaks of Monte Cornacchia, in particular near Lake Pescara. This paleolandslide concerns an area mainly affected by nature tourism. At its base, this geologically unstable area affects one of the extreme parts of the town, with mixed area uses - including residential and small-industrial uses.

After the legal orders blocking the possible transformations established by the regional bodies, the planning activity was never formally updated, awaiting the consolidation works that the orders themselves prescribed. However, this implementation process is significantly behind schedule, leaving a very large area without regulatory effectiveness and active use. In the meantime, however, activities with low transformative impact have been developed, mainly of a nature-tourism type.

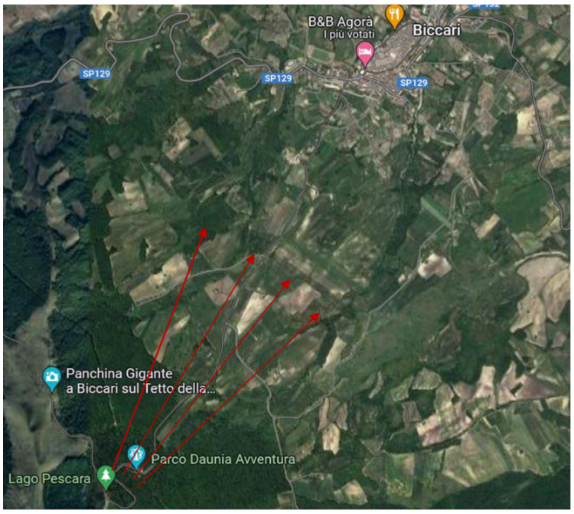

Fig.2 Indication of the paleolandslide near Lake Pescara (on a Google Maps image)

At the same time, a movement against the blocking of the transformability of these external territories has been growing, also triggering illegal construction. The municipal administration is currently exploring the possibility that these critical places can be normatively adapted following the behavior dynamics of the landslide itself. This is clearly a rather pioneering initiative, however linked to the difficulties associated with the fearful rigidity of environmental transformative constraints, typical of many Italian regions - which have always suffered from strong environmental aggression (Koutalakis, 2004). The Biccari administration invited the Polytechnic University of Bari and the University of Sannio, both in southern Italy, to deal with this complex situation (Fistola et al., 2023). They aimed to verify the possibility of setting up formal models capable of defining times, methods, quantities and dynamic rules in connection with the behavior of the landslide - to be subsequently reported in an urban plan. For this purpose, a particular research approach, namely agent-based, is currently being explored (Ferber, 1999).

4.1 Towards an agent-based approach

Methodological justification: Why agent-based modeling for non-knowledge and risk?

The complexity of spatial planning under conditions of uncertainty and community fatalism requires methodological approaches capable of representing heterogeneous behaviors, emergent dynamics, and nonlinear interactions between human and environmental systems. Traditional planning models, often based on equilibrium assumptions and homogeneous stakeholder behavior, are inadequate to address what we call "non-knowledge" – a profound uncertainty regarding future states and outcomes that characterizes fragile territorial contexts.

Agent-Based Modeling (ABM) offers distinct advantages in managing these challenges. First, it allows for the representation of heterogeneous agents with different risk perceptions, decision-making logics, and behavior patterns – an essential capability in communities where fatalistic and precautionary attitudes coexist (Bonabeau, 2002; Crooks et al., 2018). In the case of Biccari, this heterogeneity is empirically observed, with residents displaying very different attitudes toward hydrogeological risk.

Furthermore, ABM allows us to model emergent phenomena resulting from bottom-up interactions rather than top-down prescriptions. Planning processes under uncertainty are characterized precisely by emergent outcomes, which cannot be predicted by the simple sum of individual behaviors (Gilbert & Troitzsch, 2005). This is particularly relevant in contexts like Biccari, where collective outcomes arise from the interaction between individual risk perceptions, institutional constraints, and environmental dynamics.

Also, ABM offers a natural framework for jointly including human and environmental agents in the same model structure (Bousquet & Le Page, 2004). The paleolandslide at Biccari is not a mere passive constraint, but an active system whose behavior both influences and is influenced by human activities. This reciprocal relationship between sociotechnical and environmental systems cannot be adequately represented by traditional tools that consider the environment as an external parameter.

Finally, ABM supports scenario exploration and policy testing, particularly suited to "non-knowledge" contexts. Rather than seeking optimal solutions based on complete information, ABM allows us to explore a range of possible outcomes based on differentiated hypotheses about agent behaviors, institutional arrangements, and environmental conditions (Filatova et al., 2013). This aligns with our conceptual framework, which accepts uncertainty as a constitutive element of planning, not a problem to be eliminated.

The methodological choice of ABM therefore represents more than a technical decision. It reflects a philosophical stance toward planning under uncertainty, which prioritizes mutual and adaptive learning over deterministic prediction, recognizes the legitimacy of diverse forms of knowledge, and aims to understand rather than control complex territorial dynamics.

Building a layout of agents and relations

In a complex context such as an ecosystem or a sociotechnical system, agents are typically multifaceted, operating at different scales and with different roles and sometimes even expressing behaviors that vary with situational dynamics. Risk situations also include unusual, atypical, intriguing but not easily catalogable or manageable behaviors. In the case of Biccari, a community of agents seems to emerge, i.e. interested citizens, who perceive in a diversified way the risk represented by the presence of the paleolandslide - particularly in some areas of greater transformative interest. In general, there are agents who are certainly sensitive to the risks associated with the phenomena in progress. Some, however, seem to express perplexity if not reluctance to accept the presence of a real risk in these areas. Some agents simply do not believe that such a risk actually exists, as they are skeptical of the real knowledge of the experts who established the dangerousness of the areas. Other agents, while recognizing the presence of risk, perceive it in a very limited way in relation to the slow flow of the landslide. Still other agents tend to consider the inevitability of events as an integral part of everyone's life and therefore minimize the risk itself. Generally speaking, quite a few agents seem to show common characters in terms of perception and behavior. On the one hand they seem to express a fatalistic attitude, albeit to varying degrees, towards the risk of a significant landslide event. On the other hand, they seem to consider this risk, here too in a differentiated way, as an intrinsically constitutive element of every action, in particular in territorial transformations. This last vision closely resembles the concept of economic risk (Chatterjee et al., 2003).

With a blend of such characters, specific profiles of agents could be built, consistent with a teleonomic cognitive model of various composition, following for example Ferber (1999, p.16). In the case in question, a more in-depth study can characterize the agents based on their possible activities, with a relationship with the community and the territory affected by the landslide. The same agent-based approach can also hypothesize a coherent configuration of the landslide system itself. Indeed, modeling this 'environmental agent' is actually part of a long-standing, difficult line of research, with multiple attempts to address its intrinsically high degree of complexity. Given the evidently multidimensional character of the concept of environment, modeling experiences have often opted for agent models partialized only to the aspects of specific interest of the study (Bousquet & Le Page, 2004; Weyns et al., 2007; Schreinemachers & Berger, 2011). This approach seems adoptable in the present case, defining a 'paleolandslide agent' through characters of particular interest of the phenomenon studied. It is clear that the behavior of a landslide can be detected through sensor technologies specifically used in these cases (Casagli et al., 2023; Yaprak et al., 2017). The presence of a more accentuated risk induces the need for denser, more elaborate and sophisticated (and expensive) sensor networks and vice versa. Furthermore, especially in high-risk situations, actual task forces are established made up of experts and analysts from various disciplines. Through also frequent inspections, surveys and field analyses, they report the aspects of the behavior of the phenomenon being studied (Guzzetti et al., 2020). In this case, a hybrid type of behavioral model of the phenomenon can be hypothesized, made up of technological sensors and human analysts, oriented towards updating databases representing situational dynamics. It is evident that this is a partialized environmental agent, located through parameters/variables that approximate its behavior, and that interacts with the other agents generating a model of territorial dynamics oriented towards its transformation/conservation (Occelli & Rabino, 2006; Fusco et al., 2021).

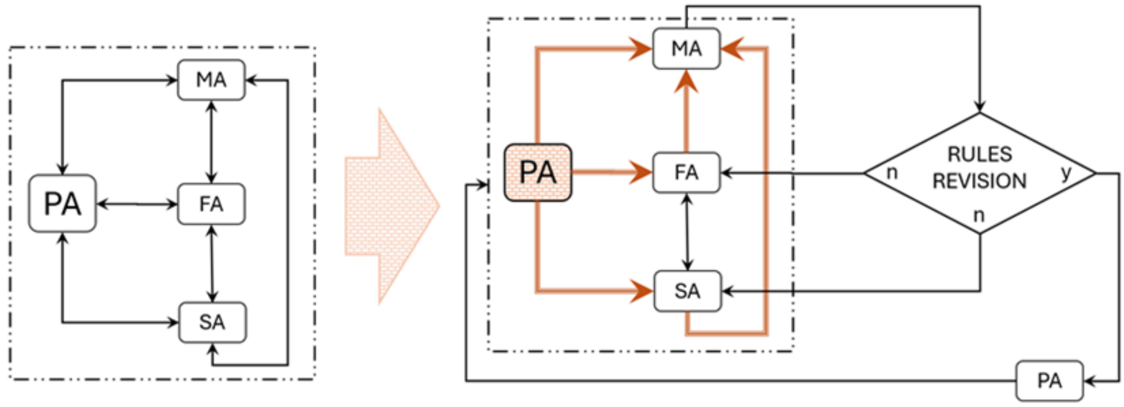

Fig.3 Simplified agent-based layout

Fig.3 schematizes a possible interaction layout between agents active in the problematic situation in question. This is a rather simplified context, both from a situational point of view and from the point of view of the agent profiles involved. Clearly, this is only an example to set the prodromes of a possible real process. From the point of view of the context, there is the paleolandslide with its slow or very slow dynamics, with the agents that in some way have an interest in it. The agents are schematized in an extremely small number, with the simple aim of showing a possible functioning of the model. On the left we see the initial equilibrium situation, characterized by the presence of four agents. The acronym SA indicates the sensitive agent, i.e. the individual who, when faced with even a minimally perceptible dangerous situation, shows acute sensitivity and therefore develops defensive, not very enterprising behavior, with the aim of maintaining a calm status quo as far as possible. The acronym FA indicates the previously mentioned fatalistic agent, i.e. that individual who shows little reactive if not indifferent behavior towards the possible dangerous event. This agent profile is intended here as an illustrative way to represent all those other types of agents that have similar behaviors, as seen before. The agent indicated with MA is intended as the civil/municipal administration, which holds the planning, regulatory prerogative of the rules established on land use. It is clear here that we are dealing with an 'agency', that is, a group of agents who contribute to defining the behavior of this collective agent towards the outside. The other collective agent is the paleolandslide, denoted PA, which we dealt with previously, too. In the left part of the figure, the initial (unstable) equilibrium condition is defined in which agents communicate with each other, mainly in terms of information exchange. Assuming that an element of modification of the equilibrium comes from the outside, we have therefore chosen the possible construction of a series of consolidation structures along the extension of the landslide. Indeed, these have long been prescribed in regional programs but have not been implemented, leaving the Biccari situation in its current precarious state. In agent-based modeling, the creation of these support structures represents a modification in the behavior of the paleolandslide agent, which tends to modify the situation and therefore the equilibrium of the system (Wooldridge, 2012). We thus move on to the right part of the figure in which the initial relationships become essentially unidirectional, from the paleolandslide towards the other agents. In particular, SA and FA agents maintain a close relationship as they are both interested in the best management of the land they own or manage. The fatalistic agent immediately turns to the administrative agent MA with an impulse to relax the constraint rules. The sensitive agent, although certainly reluctant to carry out transformative operations, could probably also tend to solicit the administrative agent in some way - perhaps due to the interaction normally taking place with the fatalistic agent. Based on these requests the administrative agent, in turn in constant (even institutional) correspondence with the paleolandslide agent regarding the changed environmental behavior in progress, can decide or not to relax the constraints. By deciding not to review the constraints, MA can simply notify the agents involved of the permanence of the previous rules. Otherwise, MA can activate a process of reviewing the rules, in particular of the spatial plan, by involving the PA planning agent. At this point the situation finds a new equilibrium - but still unstable, both because it is intrinsically characterized by instability, and because the behaviors generated by the revision of the environmental rules can affect the behavior of the paleolandslide agent and therefore determine further variations in the equilibrium. In fact, it should be underlined that the revision of the plan itself clearly represents per se an action with a possible impact on the environment and therefore a change in the behavior of the paleolandslide agent.

4.2 An experiment with NetLogo software

With the aim of exploring the potential of an agent-based approach in this complicated territorial story, we decided to use a simulation architecture. Given the very preliminary stage of the research, the simulation was done using a simple and very common software with basic generic data. Starting from the previously illustrated scheme (Fig. 3), some basic parameters were set with NetLogo 6.4.0 and more agents were hypothesized, to allow a minimally structured simulation.

Please note that the simulation described in this paper should be considered a first experimental layout rather than a validated planning tool. At this stage, model parameters are based on heuristic assumptions and literature-inspired scenarios, without calibration on real-time or high-resolution datasets. This choice is consistent with our aim of exploring how agent heterogeneity, perceptions of risk, and institutional reactions might interact in shaping long-term planning decisions under uncertainty.

A new agent list follows, rewritten to show profile behaviours, actions and relations:

- SA = Sensible Agent: (i) exhibits strong concern for unforeseen events; (ii) develops defensive behaviors in response to perceived risk; (iii) aims to maintain a calm status quo; (iv) engages in competitive or cooperative relationships with FA; (v) formulates requests to MA; (vi) activates EEA and/or BA, consistent with its risk-averse behavior; (vii) can own or manage land parcels; (viii) is satisfied when its requests achieve objectives.
- FA = Fatalist Agent: (i) shows low concern for unforeseen events; (ii) exhibits a reactive or indifferent behavior towards potential hazards; (iii) considers risk as inherent in spatial transformations; (iv) engages in competitive or cooperative relationships with SA; (v) formulates requests to MA; (vi) activates EEA and/or BA, consistent with its fatalistic behavior; (vii) can own or manage land parcels; (viii) is satisfied when its requests achieve objectives.
- MA = Municipal Administration: (i) is legally responsible for issuing a long-term local land use plan; (ii) is willing to promote regional socio-economic development through transformations; (iii) makes decisions on land use rules; (iv) makes decisions on planning, programs, and strategies for sustainable development; (v) makes decisions on physical interventions for territorial safety; (vi) decides on the application and removal of land use restrictions and permits; (vii) assigns tasks to agent P; (viii) receives feedback from agent P; (ix) receives requests from FA and SA agents; (x) receives safety feedback from agent PA; (xi) is satisfied when it legally issues an effective and safe long-term local land use plan.

- P = Planning Agent: (i) develops draft land use plans; (ii) drafts programs and rules on land use; (iii) receives requests from MA to design and/or modify plans, programs, and rules on land use; (iv) gathers knowledge and information from agents.
- PA = Paleo-landslide Agent: (i) moves slowly downwards, varying speed depending on uncertain causes and land transformations; (ii) creates territorial risk conditions; (iii) alerts agents; (iv) receives MA's decisions on land use and sustainable development; (v) its movements are sensitive to land transformations.
- BA = Building Agent: (i) carries out substantial land transformations for building development; (ii) is activated by FA or SA.
- EEA = Environmental Entrepreneurial Agent: (i) carries out minimal land transformations for environmental tourism; (ii) is activated by FA or SA.

Using NetLogo 6.4.0, the compiled code for the simulation consists of about 200 commands in 300 command strings, which are omitted here due to obvious space limitations. However, a synthetic architecture of the code can be extracted for a general clarification of the process (Tab.1).

Simulation Phase	Code Step	Key Agents Involved	Primary Actions
Initialization	`setup procedure`	PA, MA, SA, FA	- Landscape grid initialization - Agent placement - Parameter setting
Annual Cycle	`go procedure`	All agents	- Agent interaction calculations - Landslide behavior update - Satisfaction metrics recalculation
Policy Decision	`decide-pug-revision`	MA, P	- Plan revision triggers - Restriction relaxation checks - PUG draft evaluation
Project Implementation	`execute-projects`	BA, EEA	- Development project execution - Eco-tourism infrastructure build - Consolidation works
Satisfaction Update	`update-satisfaction`	SA, FA, MA	- SA: Risk perception algorithm - FA: Development gain calculus - MA: Plan effectiveness evaluation
Monitoring	`update-metrics`	PA, MA	- Velocity measurements - Stability index calculation - Risk level assessment

Tab. 1 NetLogo Simulation Architecture

In general the model develops as follows. It is a territory affected by an ancient landslide classified as PG3 (high geomorphological hazard) in the Hydrogeological Structure Plan, exhibiting diffuse cracks and fragility despite limited previous consolidation efforts. Initial hypothesized simulation conditions included a baseline landslide velocity of 20 mm/year, moderate stability levels, pre-existing urban planning (Biccari PUG) restrictions, and an environmental impact baseline of 30%. The simulations were initialized with parameters designed to reflect a plausible yet simplified condition of the Biccari landslide system. The baseline landslide velocity was set at 20 mm/year, consistent with the lower bound of the "very slow" category in the Cruden and Varnes (1996) classification for landslide movement. The initial stability level of the slope was randomized within a 40–60% range, reflecting partial consolidation measures previously undertaken, without achieving full territorial security. The initial environmental impact was fixed at 30%, qualitatively suggesting moderate anthropogenic pressure and limited development activity at the start of the simulation. The initial risk level—not directly assigned, but dynamically computed within the model—emerged between 60% and 66% in the first simulation year. This risk index is calculated via the following expression:

$$\text{Risk Level} = \min\left(100,\ 50 + \left(\frac{\text{velocity}}{\text{baseline}}\right) \times 25 - \frac{\text{stability}}{4}\right) \quad (1)$$

This formula is not derived from existing risk assessment literature but serves to generate a normalized (0–100%) risk estimate that qualitatively reflects the interplay between the dynamic behavior of the landslide and the perceived slope stability. The use of this index is not intended as a substitute of formal hazard-vulnerability-exposure models (e.g., R = H × V × E) (Burton et al., 1993). Rather, it just aims to enable a simulative exploration about system evolution and policy decision-making in a multi-agent framework.
Two simulation hypotheses were tested, differing in agent populations: Hypothesis 1 used a minimal configuration (3 SA, 3 FA), while Hypothesis 2 adopted a denser configuration (10 SA, 10 FA), to evaluate system response under different sociopolitical pressures (Tab.2).

Parameter	Hypothesis 1	Hypothesis 2
Number of Sensible Agents (SA)	3	10
Number of Fatalist Agents (FA)	3	10
Simulation Duration	20 years	20 years
Initial Landslide Velocity	20 mm/year	20 mm/year
Initial PUG Status	Initial (baseline)	Initial (baseline)
Initial Environmental Impact	30%	30%
Initial Risk Level	60–66%	60–66%
Initial Stability Level	~50%	~50%
Decision Style	Development-prone (reactive)	Safety-first (preventive)

Tab.2 Simulation Setup: Hypotheses 1 vs 2

In the first approach (development-oriented), the Municipal Administration implemented initial consolidation works while simultaneously relaxing development restrictions. This led to rapid economic development (22 projects) but caused temporary destabilization of the paleolandslide, necessitating reactive measures when landslide velocity increased from 12 mm/year to 31 mm/year and risk levels escalated to 77.5%. The situation required restriction reinstatement followed by additional consolidation works before reaching stability. While ultimately achieving 100% landslide stability and high stakeholder satisfaction, this approach resulted in significant environmental impact (56%) and required 17 years to reach equilibrium.
The second approach (safety-first) prioritized comprehensive consolidation works (5 interventions) before permitting development. This strategy progressively reduced landslide velocity from 19 mm/year to zero while improving stability from 52.5% to 100%. Only after achieving substantial stabilization were restrictions relaxed, leading to minimal development (2 projects) but rapid attainment of equilibrium (by year 12) with minimal environmental impact (32%). All stakeholder groups achieved high satisfaction levels (SA: 73%, FA: 74%, MA: 100%). It should be noted that while hypothesis 2 increases the number of agents, their binary classification (SA/FA) reflects intentional simplification to isolate the impact of community pressure on governance decisions, not to replicate real-world behavioral diversity.
In the end, the simulation highlights some key findings relevant to landslide risk governance. First, the timing of interventions has significantly impacted both risk levels and stakeholder satisfaction, with early consolidation works providing more sustainable outcomes than reactive approaches. Second, development pressures and risk management could be balanced through adaptive governance that responded to monitored environmental conditions. Additionally, stakeholder satisfaction did not necessarily require

extensive development if safety and stability are adequately addressed first - suggesting that risk-sensitive planning can achieve social acceptance. Finally, multi-agent systems could somehow effectively model the complex feedback loops between physical processes (landslide behavior), governance decisions (PUG restrictions and consolidation works), and stakeholder responses.

These simulation outcomes seem to confirm that governance processes in landslide-prone territories should prioritize stability-establishment before development authorization. The simulation suggests that with limited development activity (only 2 projects versus 22), stakeholder satisfaction can reach comparable levels when safety concerns are comprehensively addressed. This challenges conventional assumptions about necessary trade-offs between risk reduction and economic development, exhibiting interesting perspectives of decision and policymaking.

In this initial stage we have limited the reasoning to a list of possible agents active in the context and to an exemplary diagram of a possible process. We will subsequently explore the levels, quantity and quality of mutual relationships and decisions induced by the dynamics that may occur. In this area, a large line of research has long been developed on aggregate approaches to the modeling of collective decisions which can be a useful reference (Scott, 2018; Santoro et al., 2024; Salvati et al., 2013). On the other hand, the markedly qualitative and emotion/belief-based aspect of decision-making problems may suggest a more structured and disaggregated approach, inspired by intelligent agent-based models derived from computer science (Wooldridge, 2002). This could allow the creation of dynamic support architectures for risk governance models, which prefigure scenarios of dynamic management of urban/anthropic spaces - at least in some environments with slow instability and low community perceptions. Our study group has been engaged in these research topics for a significant time, with research on possible hybrid models of support for cognitive interaction and decision-making in collective environments of complex knowledge (Borri et al., 2018; Stufano Melone et al., 2019). When asked about these perspectives, the administrative managers of the regional control body showed interest, while complaining about a general inadequacy of the current administrative and territorial management laws towards organizational innovations of this type.

4.3 Model limitations and methodological considerations

Despite the valuable insights provided by our NetLogo simulation, it is necessary to acknowledge some important limitations, both related to the model and its technical implementation.

First, the model parameters are based on heuristic assumptions and not systematic empirical calibration. Initial landslide velocity, stability levels, and risk formulas are approximations drawn from general literature rather than Biccari-specific data, reflecting the exploratory nature of the study and the difficulty of acquiring high-resolution data in small-municipal contexts.

Furthermore, the binary classification of agents as "sensitive" and "fatalistic" is a useful simplification for isolating key dynamics but certainly not exhaustive. Indeed, it captures the complexity and actual gradation of risk perceptions and behaviors, nor their temporal evolution.

From the perspective of environmental system modeling, there is a further limitation. The paleolandslide agent is represented with simplified algorithms that abstract from complex geomorphological processes. The velocity-stability relationships used here are essentially functional and cannot represent detailed physical simulations of complex slope dynamics.

Finally, there are limitations inherent in the NetLogo platform itself. While often considered well-suited for exploratory models (e.g., Murphy, 2025), the platform imposes constraints on computational complexity and performance. The discrete, grid-based model may not capture the continuous dynamics and fine spatial differentiations present in complex spatial environments.

These limitations suggest areas for improvement in future work, including integration with geological monitoring systems, more sophisticated behavioral algorithms, and hybrid ontology-based approaches that combine agent-based modeling with detailed physical models.

5. Discussion, conclusions and follow up

A sense of fatalism emerges which seems to influence the perception of phenomena and the interpretation of future events. Fatalism is present in many cases worldwide, for example in cities exposed to tsunamis, or high seismicity, or close to volcanic activity.

The notion of fatalism is generally understood as an attitude of resignation toward future events regarded as inevitable (Rice, 2024). In philosophical discourse, however, the term typically denotes the thesis that human agents lack the power to act otherwise than they in fact do. The classical formulation of the fatalist problem can be found in Aristotle's Περὶ ἑρμηνείας (On Interpretation), written between 384 and 322 B.C.E., where he examines whether, for any given proposition, it must be the case that either its affirmation or its negation is true (Rice, 2024). Within the framework of Aristotelian logical fatalism, if every statement concerning the future already possesses a determinate truth value – either true or false – then it follows that the course of events could not occur differently and thus lies beyond our control. Nevertheless, the philosophical validity of fatalism remains an unresolved and debated issue (Rice, 2024).

Our group aims to study the possibility of integrating the sensor networks typically present in these places with complex sensory models built on the perception of the inhabitants, on surveys and the intuition of multidisciplinary experts and more. Furthermore, in the case of Biccari, the possibility of refining the research on the phenomenon of fatalism is explored, with the aim of drawing indications for the construction of support models for predictions and decisions. The essence of places can often be found in the quality of having been to a specific place. Our knowledge of places can come from experiences, from the stories that structure ideas, from feelings about them. There is therefore a 'subjective knowledge' of places, which adds up in a consonance of intentions and experiences in a rich, collective knowledge of the chorus of individuals who form it, which becomes memory and perspective. But often intentionalities, which even start from a knowledge of places generally common to the same group of agents, are crowded with unclear projects, or which do not look at the consonance of collective intentions, or which in any case ignore the consequences of certain more systemic choices. or needs – contemporary to taking a certain action. 'Subjective knowledge' is a sort of representation of places and a representation varies from subject to subject and also in the life of an agent, anthropic or not. And so, from the world of research in the field of territorial planning disciplines, a different way of interpreting and reading the territory is proposed in the real and factual world. The idea is that this can guarantee a management and planning of the territory that is finally advanced compared to what has been used in planning practice in recent decades, for the identification of an invisible but already true future and resilience in the seeds scattered in the present.

Fatalism is not merely a "feeling" or attitude of resignation, as the more popular sense might imply; rather, in its older semantic and conceptual layers, it refers to a logical-metaphysical structure touching upon freedom, the capacity for action, and the truth of future-tense propositions and a long chain of debate in philosophy didn't solve its problem yet. In the field of environmental and territorial planning, a comparable epistemic or symbolic structure may underline certain forms of reasoning and behaviour, extending far beyond a merely passive or indifferent attitude.

If what is to happen is in some sense already true or necessary, then processes such as knowledge gathering, modelling, and participatory action acquire a different dimension: since we do not know what is true in what must occur, an attitude oriented toward protection, preparedness, and the principle of minimal harm becomes the most strategic course of action – at least in view of an awareness of what is feasible, even within a framework of a priori ignorance concerning what may or may not happen.

Another instance of ignorance that may give rise to broadly fatalistic attitudes concerns what we do not know yet already exists in our contemporary world – either as a cause in potentiality or as an effect that has already triggered, or will trigger, a chain of events leading to previously unforeseen but already latent consequences (Gumbrecht, 2014; Stufano Melone & Camarda, 2022).

Accordingly, the collection, management, and representation of knowledge should serve as instruments of action and decision that are as effective as possible in preventing what can be foreseen as likely. The knowledge entering the planning process must also include that which emerges from participatory processes, in order to identify and possibly mitigate any 'fatalistic' attitude. This is essential to avoid deliberately entering situations of poorly perceived hazard and risk, and to ensure adequate self-protection and collective resilience.

This contribution must be understood as a preliminary and exploratory step within a broader research trajectory. The model and simulation presented do not aim to offer definitive results, but rather to outline a conceptual framework for managing risk and non-knowledge in planning contexts affected by environmental fragility and socio-cultural fatalism. This exploratory work highlights how dynamic agent-based modelling, despite its current simplifications, offers a flexible alternative to static planning frameworks that often fail to capture complex interactions between environmental risks and community behaviors. Future implementations could introduce gradient risk perception (e.g., moderately cautious agents) or external institutional actors (e.g., regional agencies) to enhance realism. Also, future developments will focus on the empirical calibration of the simulation, the integration of sensor-based and participatory data, and the validation of the model through comparative and historical case analyses. The goal is to progressively refine this approach into a flexible and adaptive decision-support tool, capable of navigating uncertainty without resorting to deterministic or overly rigid planning paradigms.

As a whole, we think that an ontological approach will be useful to model and structure the knowledge collected, even in real time, by these complex and hybrid sensor networks (Borgo et al., 2021). Due to the ability to structure knowledge through the formalization of conceptual relationships, we think that applied ontologies should be particularly suitable for managing complex and dynamic knowledge – and non-knowledge as well. Therefore, our future work will be just oriented to explore such modelling perspectives.

Author's contribution

Conceptualization, methodology, data collection, data curation and analysis: M.R.S.M. and D.C.. Writing: sect.4.1. 4.2 and 4.3: D.C; all other sections: M.R.S.M.. The authors are grateful to Dino Borri for early modelling ideas, particularly for his intriguing suggestions about fatalism issues in planning. All authors have read and agreed to the published version of the manuscript.

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