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Mapping the Discourse of Sustainability in Medicine: A Bibliometric and Interdisciplinary Analysis (2015–2025)

მედიცინაში მდგრადობის დისკურსის რუკა: ბიბლიომეტრიული და ინტერდისციპლინარული ანალიზი (2015–2025)

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Abstract

Background: In recent years, the concept of sustainability has become central to global health discourse, yet its meaning within medical academia remains fragmented and variably defined. While sustainability originated as an ecological and economic principle, its integration into medicine reflects a shift from healing individual patients to maintaining the resilience of health systems, communities, and ecosystems. **Objectives:** This study investigates how sustainability is conceptualised and articulated in medical academic literature, identifying its main thematic domains, disciplinary intersections, and conceptual gaps. **Methods:** A bibliometric and semantic analysis was conducted on 7,161 PubMed-indexed articles published between 2015 and 2025 containing the terms “sustainability” or “sustainable” in titles or abstracts. Using VOSviewer, 16,348 unique terms were mapped to identify co-occurrence clusters and emerging semantic trends. **Results:** Five major clusters were identified: (1) health policy and governance; (2) implementation and organisational innovation; (3) social and demographic determinants; (4) ecological and planetary sustainability; and (5) professional and behavioural sustainability. The results reveal a transition from a narrow economic understanding of sustainability toward an integrative paradigm connecting health equity, environmental responsibility, and institutional resilience. **Conclusions:** Medicine redefines sustainability as an operational and ethical framework linking clinical effectiveness, social justice, and ecological balance. This study highlights conceptual fragmentation and underexplored dimensions—especially ecological and professional sustainability—offering a foundation for interdisciplinary dialogue and evidence-informed policy design.

Keywords: Bibliometric analysis, Health systems, Implementation science, Medical discourse, Planetary health, Sustainability, Sustainable development, VOSviewer.

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აბატრაქტი

შესავალი: ბოლო წლებში მდგრადობის კონცეფცია გლობალური ჯანდაცვის დისკურსის ცენტრალურ ადგილს იკავებს, თუმცა მისი მნიშვნელობა სამედიცინო აკადემიურ წრეებში ფრაგმენტული და ცვალებადად განსაზღვრული რჩება. მიუხედავად იმისა, რომ მდგრადობა

წარმოიშვა, როგორც ეკოლოგიური და ეკონომიკური პრინციპი, მისი მედიცინაში ინტეგრაცია ასახავს გადასვლას ინდივიდუალური პაციენტების განკურნებიდან ჯანდაცვის სისტემების, თემებისა და ეკოსისტემების მდგრადობის შენარჩუნებაზე. კვლევის მიზანია, თუ როგორ არის მდგრადობა კონცეპტუალიზებული და არტიკულირებული სამედიცინო აკადემიურ ლიტერატურაში, მისი ძირითადი თემატური დომენების, დისციპლინური კვეთებისა და კონცეპტუალური ხარვეზების იდენტიფიცირებით. **მეთოდები:** ჩატარდა ბიბლიომეტრიული და სემანტიკური ანალიზი PubMed-ის ინდექსირებულ სტატიაზე, რომლებიც გამოქვეყნდა 2015-დან 2025 წლამდე, რომლებიც შეიცავდა ტერმინებს „მდგრადობა“ ან „მდგრადი“ სათაურებში ან რეფერატებში. **შედეგები:** გამოვლინდა ხუთი ძირითადი კლასი: (1) ჯანდაცვის პოლიტიკა და მმართველობა; (2) განხორციელება და ორგანიზაციული ინოვაცია; (3) სოციალური და დემოგრაფიული განმსაზღვრელი ფაქტორები; (4) ეკოლოგიური და პლანეტარული მდგრადობა; და (5) პროფესიული და ქცევითი მდგრადობა. შედეგები ავლენს გადასვლას მდგრადობის ვიწრო ეკონომიკური გაგებიდან ინტეგრაციულ პარადიგმაზე, რომელიც აკავშირებს ჯანდაცვის თანასწორობას, გარემოსდაცვით პასუხისმგებლობას და ინსტიტუციურ მდგრადობას. **დასკვნები:** მედიცინა ხელახლა განსაზღვრავს მდგრადობას, როგორც ოპერაციულ და ეთიკურ ჩარჩოს, რომელიც აკავშირებს კლინიკურ ეფექტურობას, სოციალურ სამართლიანობას და ეკოლოგიურ ბალანსს. კვლევა ხაზს უსვამს კონცეპტუალურ ფრაგმენტაციას და ნაკლებად შესწავლილ განზომილებებს - განსაკუთრებით ეკოლოგიურ და პროფესიულ მდგრადობას - რაც საფუძველს ქმნის ინტერდისციპლინარული დიალოგისა და მტკიცებულებებზე დაფუძნებული პოლიტიკის შემუშავებისთვის.

საკვანძო სიტყვები: ბიბლიომეტრიული ანალიზი, ჯანდაცვის სისტემები, სამედიცინო დისკურსი, მდგრადობა, მდგრადი განვითარება.

რეკომენდირებული ციტირება: რადუ-მიჰაი დუმიტრესკუ, ადრიან-ნიკოლაე დენი (2026). მედიცინაში მდგრადობის დისკურსის რუკა: ბიბლიომეტრიული და ინტერდისციპლინარული ანალიზი (2015–2025). *ჯანდაცვის პოლიტიკა, ეკონომიკა და სოციოლოგია,* 10 (1). DOI: https://doi.org/10.52340/healthecosoc.2026.10.01.3.

1. Introduction

1.1. The global context of sustainability

Since the publication of the Brundtland Report – *"Our Common Future"* (World Commission on Environment and Development, 1987), the concept of sustainability has become a global paradigm that is reshaping science, politics and social ethics. In the classic sense of the aforementioned report, sustainability refers to "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Subsequently, through works such as *"The Limits to Growth"* (Meadows et al., 1972) and *"Doughnut Economics"* (Raworth, 2018), the idea crystallised that sustainability is not just an ecological concept, but a principle of balance between natural, economic and social systems.

With the launch of *The Sustainable Development Goals* (SDGs) by the United Nations in 2015, the health dimension became central, "Goal 3 — Ensure healthy lives and promote well-being for all at all ages" and explicitly links health to sustainability. This association has generated a transformation of the medical paradigm, causing health systems to become not only efficient but also sustainable (World Health Organisation, 2022; World Bank, 2023).

1.2. From public health to planetary health

Over the past two decades, the concepts of "global health", "planetary health" and "One Health" have redefined the boundaries of medicine (Whitmee et al., 2015). These paradigms recognise the interdependence between human, animal and environmental health, which has led to the expansion of medicine's responsibility beyond the biological boundaries of the body to complex ecological, economic and social systems (Shomaker et al., 2013; Horton et al., 2014).

In this context, sustainability becomes an epistemological dimension of health, not just an administrative goal. It involves, simultaneously: (1) protecting natural resources (ecological sustainability), (2) strengthening institutions (institutional sustainability), (3) ensuring equity and social justice (social sustainability), and (4) maintaining the competence and motivation of medical staff (professional sustainability). This integrative vision, often referred to as "health in all policies", reconfigures the role of medicine as a discipline of interdependencies (Kickbusch & Gleicher, 2011).

1.3. Sustainability in academic medicine: an emerging paradigm

Although medicine has long been concerned with efficiency, safety and quality, it has only recently begun to treat sustainability as a research topic in its own right. The term appears increasingly often in articles on the implementation of medical interventions ("implementation science", "programme continuation"), health system governance ("resilience", "health system strengthening"), the ecological impact of hospitals ("green healthcare", "carbon footprint") and sustainable professional training ("sustainable medical education"). This process indicates the institutionalisation of sustainability in medical discourse, a conceptual shift from "healing" to "maintaining health over time".

However, the literature is heterogeneous and fragmented; the term is used with different meanings (financial, social, ecological, organisational), without a unified framework (Moore et al., 2017; Scheirer & Dearing, 2011). Therefore, a systematic analysis is needed to clarify how sustainability is understood and used in academic medicine, how it compares to other fields (environment, economics, sociology) and how its scientific language evolves over time.

1.4. Justification of the study and contribution of the research

This research stems from the belief that scientific language is a mirror of epistemological transformations. The bibliometric and semantic analysis of PubMed literature (2015–2025) provides an insight into how medicine conceptualises sustainability, not only what it says about it, but how it says it, in what terms, in what contexts and how it has evolved over time.

The relevance of this analysis is threefold: (1) theoretical (it clarifies the multiple meanings of medical sustainability and their relationship with other scientific paradigms), (2) methodological (it uses bibliometric tools – VOSviewer – to map interdisciplinary discourse) and (3) practical (it provides useful information for health system governance, medical education and the formulation of sustainable public policies). At a time when medicine is challenged by climate crises, pandemics and economic pressures, understanding the discourse on sustainability becomes not just an academic exercise, but a strategic imperative.

1.5. Study objectives

The article aims to:

(1) to map the academic discourse on sustainability in contemporary medicine (2015–2025);

(2) to identify the main semantic clusters and paradigms of meaning;

(3) to compare the medical conceptualisation of sustainability with approaches in other fields (ecology, economics, sociology);

(4) highlight gaps and future directions for research.

In this way, the study contributes to the development of an integrative vision of sustainability in health, connecting medical science with global social and ecological responsibility.

1.6. Theoretical framework: the concept of sustainability in health sciences

Dimensions of sustainability in health. Recent literature (Moore et al., 2017; Scheirer & Dearing, 2011; World Bank, 2023) identifies four main dimensions of sustainability in health sciences.

Financial sustainability refers to the ability of health systems to ensure continuity of services without excessive dependence on temporary or external funding. This involves cost-effective policies, investments in prevention and innovation, and crisis-adaptable financing models (World Bank, 2023; World Bank, 2021). In public policy literature, the term is often synonymous with "viability" or "health system endurance" (Kruk et al., 2015).

Institutional sustainability describes the capacity of health organisations to maintain performance and adaptability over time, in the context of socio-technological changes. It includes dimensions such as leadership, organisational culture, knowledge transfer and staff retention. In implementation science research,

this form of sustainability is associated with "programme continuation", i.e. maintaining interventions after funding has ended (Shelton et al., 2018; Wiltsey Stirman et al., 2012).

Environmental sustainability is an emerging dimension, defined as reducing the carbon footprint and environmental impact of medical practices (Karliner & Slotterback, 2019; Whitmee et al., 2015). Healthcare systems are responsible for approximately 5% of global CO_2 emissions, and green healthcare is becoming a strategic priority in high-income countries (Lenzen et al., 2020). This dimension extends medicine beyond patient ethics to a planetary ethic of care.

Professional and human sustainability refers to the ability of healthcare professionals to work effectively, ethically and empathetically in the long term, without moral or physical exhaustion (West & Shanafelt, 2007). This form of sustainability includes factors such as motivation, work-life balance, continuing education and the psychological health of medical staff. This often-neglected dimension is essential to the functioning of systems; there are no sustainable institutions without sustainable professionals.

Sustainability as an epistemological paradigm must be taken into account. Beyond its operational dimensions, sustainability is becoming an epistemological framework that redefines how medicine conceives knowledge, responsibility and progress. In a world characterised by systemic interdependencies (health, climate, technology), medicine can no longer function as an isolated discipline. The concept of "planetary health" (Whitmee et al., 2015) proposes a "trans-systemic" epistemology, i.e. a vision that integrates biology, economics, ecology and culture into a single cognitive ecosystem. This paradigm involves: (1) moving from clinical reductionism to systems thinking, (2) moving from individual healing to collective and ecological care, and (3) migrating from efficiency to continuity as a fundamental value. Therefore, sustainability is no longer just a goal of medicine, but a principle for organising medical knowledge (Horton & Lo, 2015).

Interdisciplinary integration and conceptual challenges are becoming a natural path. However, despite semantic expansion, fragmentation of discourse persists. Medicine, economics, sociology and ecology use the term "sustainability" with partially different meanings: ecologists emphasise conservation, economists emphasise efficiency, sociologists emphasise cohesion, and doctors emphasise resilience and continuity. This terminological divergence leads to epistemic incommensurability (Funtowicz & Ravetz, 1993). Therefore, interdisciplinary knowledge transfer must be accompanied by conceptual translation, not just formal collaboration. Bibliometric and network analyses (such as the present one) contribute to this translation by identifying points of convergence and discontinuity between scientific languages.

Sustainability in health sciences is an umbrella concept that is multidimensional and evolving. It combines: (1) economic functionality (maintaining financial resources), (2) institutional resilience (ability to adapt and learn), (3) ecological responsibility (reducing environmental impact), and (4) human and ethical continuity (professional well-being and social equity). Thus, sustainable medicine is not only an applied field, but also a new way of thinking about the relationship between life, resources and knowledge, an epistemological model for the sciences of the future.

Methodology

Data sources. The search was conducted in PubMed, using the query formula:

("sustainability"[Title/Abstract] OR "sustainable"[Title/Abstract]) AND ("health"[Title/Abstract] OR "healthcare"[Title/Abstract] OR "health systems"[Title/Abstract]) AND ("2015"[Date - Publication]: "2025"[Date - Publication]) AND (English[Language]). The result was a set of 7,161 articles published between January 2015 and October 2025.

Data processing. The metadata (title, abstract, MeSH keywords) were exported in .txt format and analysed with VOSviewer 1.6.20. A total of 16,348 unique terms were identified; the inclusion threshold was set at a minimum of 5 occurrences. Of these, 1,872 terms met the criterion, and 243 had more than 40 occurrences. A co-occurrence map was created at a threshold of 5 (Figure 1) and one at a threshold of 40 (Figure 2) in order to assess which elements are fundamental, already well structured, and which are emerging or peripheral. The second map was also analysed from the perspective of density (Figure 3).

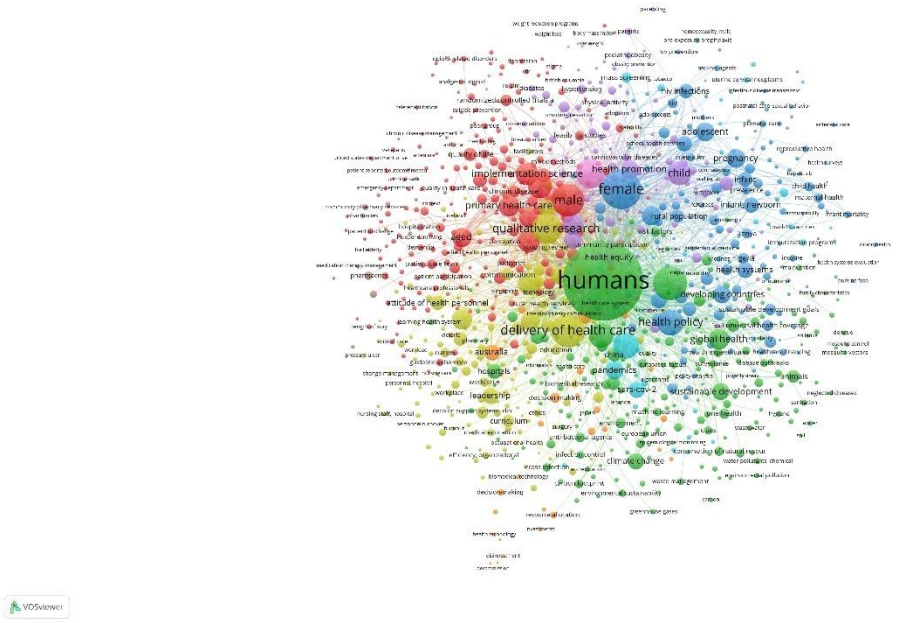

Figure 1: Co-occurrnece map (threshold of 5)

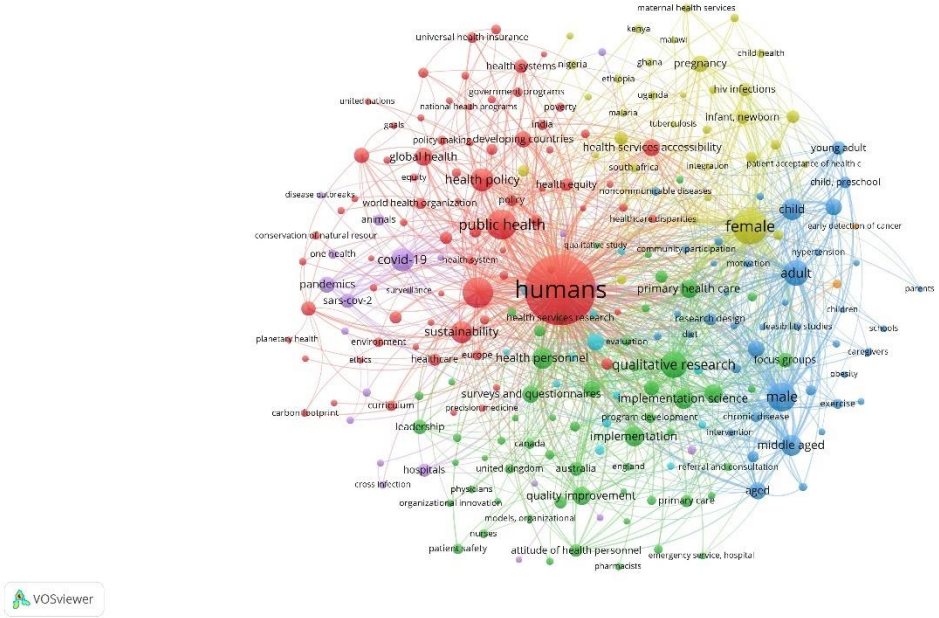

Figure 2: Co-occurrnece map (threshold of 40)

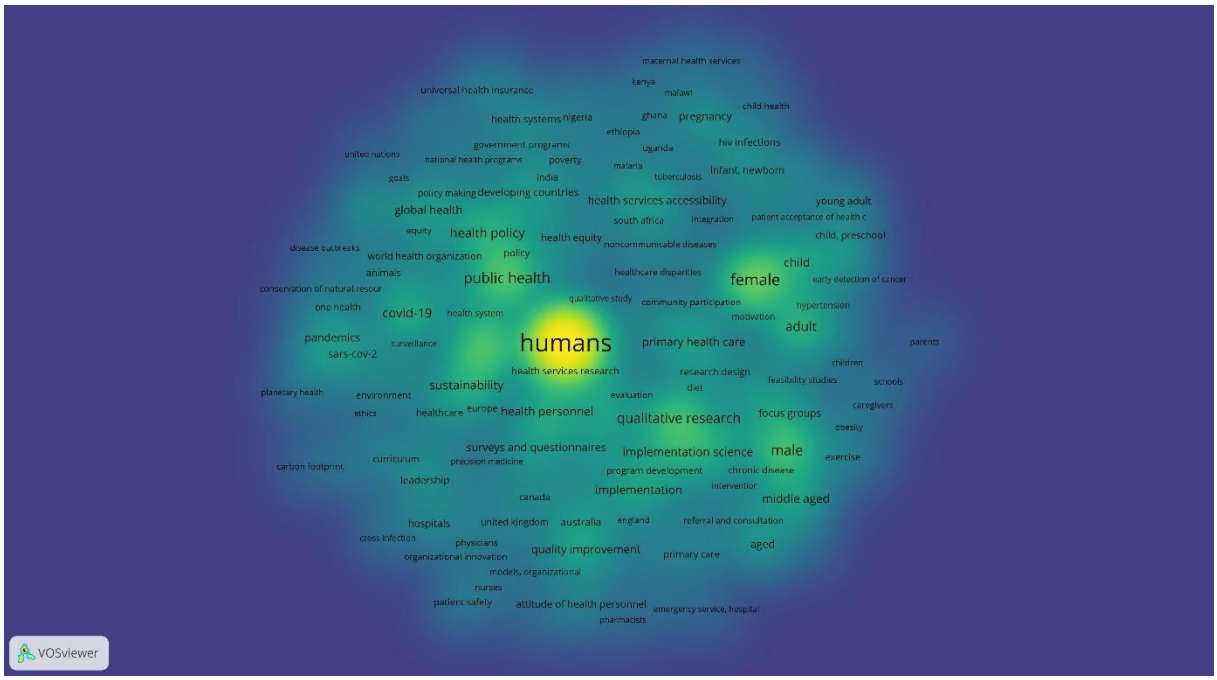

Figure 3: Bibliometric map at co-occurrence threshold of 40 - term density representation

Network analysis. The term co-occurrence analysis method was used, with association strength normalisation. The resulting networks were automatically coloured by the VOSviewer algorithm, and interpretation was based on density and semantic proximity.

Results

Bibliometric analysis

General structure. The centre of the network (analysing the high-density map, at a threshold of 5) is dominated by the terms "humans", "public health" and "health policy", suggesting the anthropocentric orientation of medical research. Five major clusters define the structure of the discourse; these will be analysed in turn.

Cluster 1 – Governance and health policies (red). The main terms are "public health", "global health", "health systems", "health equity", "universal health coverage", "pandemics", "COVID-19", "developing countries". This group reflects the macro-systemic dimension of sustainability: global health governance, equity of access, systemic resilience, and the integration of Sustainable Development Goals (SDGs). After 2020, the emergence of the terms "COVID-19" and "pandemics" suggests a reconfiguration of the discourse around the idea of sustainability as adaptability.

Cluster 2 – Implementation and organisational innovation (green). This contains terms such as: "implementation science", "quality improvement", "leadership", "organisational change", "guideline adherence", "programme development". Here, sustainability is conceptualised as the durability of interventions. Recent literature addresses sustainability as a phase of the implementation cycle, where the focus is on maintaining impact and organisational adaptability (Moore et al., 2017; Scheirer & Dearing, 2011).

Cluster 3 – Social and demographic determinants (blue). This cluster includes terms such as: "maternal health", "infant, newborn", "community participation", "primary health care", "adolescent", "female", "equity". The cluster highlights the link between sustainability and social equity, emphasising the continuity of public health programmes and community participation. It is the "human" dimension of sustainability, focused on universal access and the inclusion of vulnerable groups.

Cluster 4 – Ecological and planetary sustainability (purple). The main terms are "climate change", "carbon footprint", "environmental pollution", "waste management", "planetary health", "one health". This group illustrates the emergence of a health ecology, where sustainability takes on an interspecific and interdependent meaning. The associated terms indicate a focus on reducing the carbon footprint and

integrating environmental ethics into health policies (World Health Organisation, 2020; World Health Organisation, 2022).

Cluster 5 – Behavioural and professional sustainability (yellow). In this cluster, we find terms such as: "attitude of health personnel", "motivation", "leadership", "workforce", "qualitative research". This lexical area expresses the micro-organisational dimension of sustainability, where the focus is on human resources, institutional culture and the motivation of medical staff. The discourse becomes one of professional resilience.

Comparative analysis of co-occurrence maps (threshold 5 vs. threshold 40)

The two co-occurrence maps generated by VOSviewer illustrate two distinct levels of academic medical language related to sustainability: one extensive and diverse (threshold 5), which captures the interdisciplinary richness, and one filtered and concentrated (threshold 40), which reflects the dominant cognitive core.

By contrast, the threshold 40 map reduces the vocabulary to 243 terms, concentrating the discourse around the nodes "humans", "public health", "health policy", "implementation", and "sustainability". This semantic filtering reveals a hierarchy of meanings, in which institutional and normative domains dominate, while ecological and reflexive ones become peripheral.

Change in the dominant type of sustainability. A comparison of the two thresholds shows a shift from plural and dynamic sustainability (economic, social, ecological, professional) to institutionalised sustainability, focused on politics, governance, and public health. Thus, the low threshold map expresses an exploratory vision, while the high threshold map captures the stabilisation of medical discourse around the WHO-SDG3 framework. In epistemic terms, medicine is moving from "sustainability as an interdisciplinary ideal" to "sustainability as a governance tool".

Transformation of semantic centres. In threshold map 5, the nodes "implementation science", "climate change", "planetary health" and "equity" are intensely connected but dispersed, suggesting the coexistence of multiple paradigms. In threshold map 40, these concepts lose visibility, being replaced by standardised terms ("health policy", "public health", "humans"), which show institutional maturation and reduced conceptual diversity. This compression of language suggests that sustainability has become part of the dominant discourse, but also that it risks losing the interdisciplinary complexity that gave it its original meaning.

Interdisciplinary distribution. In the extended map, medicine appears as a pivotal discipline, connecting terms from ecology ("climate change"), economics ("financing") and social sciences ("community engagement", "equity"). In the restricted map, most terms come from the field of health policy and systemic management. Thus, interdisciplinarity fades in favour of medical institutional autonomy, in which sustainability is "medicalised".

Epistemological significance. Comparing the two maps reveals a bidirectional movement of meaning: semantic expansion (medical sustainability absorbs external languages, such as ecological, economic or social) and institutional reduction (these languages are reconfigured to serve policy and management functions). Thus, medicine becomes a space for epistemological translation, where global concepts are reinterpreted in terms of continuity, resilience and efficiency.

Interpretative analysis of the density map (threshold 40). The overall configuration highlights the "hot" core of medical discourse, dominated by the terms: "humans", "public health", "health policy", "global health", "implementation", "sustainability", "qualitative research" and "COVID-19". The yellow colour (intense) signifies the maximum density of co-occurrences, while the green and blue areas indicate emerging or peripheral areas. The central core (health as an institutional system) is characterised by the simultaneous presence of the terms "public health", "health policy" and "health systems"; this shows that sustainability is predominantly associated with institutional performance and resilience. In fact, the term "sustainability" is placed between "policy" and "implementation", suggesting that medicine understands sustainability through instruments of action and governance, not as an ecological principle. This confirms a managerial orientation; sustainability is seen as maintaining functionality, not as reconfiguring the human-environment relationship. Areas of medium intensity (global health and pandemics) contain terms such as "global health", "COVID-19", "pandemics", "resilience", and "health equity" occupy the yellow-green transition zone. They reflect a post-2020 shift in discourse towards systemic resilience, triggered by the experience of the pandemic. Sustainability becomes synonymous with the ability to withstand shocks, leading towards a technical transformation of the concept. Emerging areas (ethics, ecology and professional training) are represented in

the peripheral shades (blue-green) and terms such as "planetary health", "ethics", "environment", "curriculum", "leadership", and "carbon footprint" appear. Although they are in the minority, they indicate new epistemological directions: (1) the greening of medicine (through the "planetary health" approach), the humanisation of systems (through the integration of leadership and professional well-being) and the moralisation of medical science (through ethics and social responsibility). This semantic periphery suggests the future language of medical sustainability: the integration of the ethical and planetary dimensions into health science.

Notable absences. The absence of terms such as "environmental justice", "green hospital", "life-cycle assessment" or "waste management" is noteworthy, confirming the underdevelopment of the concrete ecological dimension. Although medicine takes up the discourse on the planet and the environment, it remains declarative, not operational.

Epistemological implications. Analysed together, the co-occurrence maps (thresholds 5 and 40) and the density map outline an evolutionary narrative of medical sustainability between 2015 and 2025, as can be seen in Table 1.

Period	Dominant paradigm	Key terms	Epistemological meaning
2015–2018	Institutional	"policy", "financing", "system"	Sustainability as economic efficiency and continuity
2019–2021	Resilience and adaptation	"COVID-19", "resilience", "global health"	Sustainability in terms of crisis response capacity
2022–2025	Emerging ethical-ecological	"Planetary health", "leadership", "ethics"	Sustainability as a balance between humans, society and the environment

Table 1: The narrative evolution of sustainability in medicine (2015-2025)

These stages suggest an evolution from technocracy to reflexivity, i.e. from an operational concept to a moral and planetary one.

The central tension is represented by the institutional vs. ecological relationship. The three maps indicate a tension between two ways of understanding sustainability: institutional (based on continuity, efficiency and control) vs. ecological (based on interdependence, ethics and responsibility). Current medical discourse favours the former, but the lexical periphery shows an epistemological pressure towards the latter. This can be interpreted as medicine's transition towards a science of planetary sustainability ("planetary health science").

The role of medicine as an interdisciplinary interface. The maps confirm that medicine functions as a discipline for translating concepts; it takes concepts from economics ("efficiency"), sociology ("equity") and ecology ("resilience", "planetary health") and integrates them into an applied language. Through this function, medicine becomes an epistemic laboratory of sustainability, where abstract theories are transformed into institutional practices.

Overall, the comparative and interpretative analysis of the VOSviewer maps shows that the discourse on sustainability in academic medicine is shifting from a language of efficiency to a language of balance. Medical sustainability is no longer just a condition of systems, but becomes a form of reflexive knowledge that unites the biological, social and planetary dimensions of health. In symbolic terms, the shift from the polycentric map (threshold 5) to the monocentric map (threshold 40) and to the density of "humans" marks the transition of medicine from technocracy to humanity, from treatment to the maintenance of life as a complex phenomenon. This is the epistemological contribution of sustainability, the transformation of medicine from the science of healing to the science of continuity of existence.

Research gaps identified in the discourse on medical sustainability

Conceptual gap - the absence of a unified theoretical framework. Although the term "sustainability" is ubiquitous in medical literature, there is no commonly accepted operational definition. The term is used polysemantic, from "financial sustainability" to "planetary sustainability", without conceptual

clarity. Only a few papers (e.g. Moore et al., 2017) propose coherent conceptual frameworks. There is a lack of integrative models linking clinical, institutional, social and ecological sustainability into a single reference system. As a result, there is a lack of comparability between studies and the impossibility of formulating universal indicators for "sustainability in health".

Methodological gap – limitation of measurement tools. Most studies identify sustainability through indirect proxies (programme continuity, costs, staff satisfaction) rather than standardised measurements. There is no consensus on methods for assessing the sustainability of medical interventions. The absence of common "indices" and "scorecards" hinders the comparative assessment of health policies. Life-cycle assessment and environmental impact methods (common in environmental sciences) are rarely applied in the medical field. As a result, it is difficult to quantify the real impact of sustainability on population health or the environment.

Thematic gap - imbalance between economic, social and environmental dimensions. Lexical analysis shows that medical literature is dominated by economic and institutional terms ("health financing", "policy", "efficiency"), but underdeveloped in terms of the ecological and planetary dimensions ("carbon footprint", "green hospitals", "one health" only appear after 2019). Furthermore, professional sustainability ("health of medical staff", "burnout", "motivation") remains marginal, even though it is an essential determinant of the resilience of health systems. Current medical discourse prioritises efficiency and costs, but neglects institutional ecology and human well-being.

Geographical gap – the dominance of the global northern discourse. The PubMed analysis highlights an overrepresentation of articles from high-income countries (USA, UK, Canada, Australia, Netherlands). Low- and middle-income countries, where sustainability has a different meaning (systemic survival, limited resources), are underrepresented. Associated terms such as "low-income countries" or "developing regions" rarely appear as central nodes. Consequently, the global discourse on medical sustainability is structured from the perspective of abundant resources, not vulnerable contexts, and therefore risks imposing inappropriate universalist models.

Epistemological gap – the absence of dialogue between disciplinary paradigms. Although the term "sustainability" is borrowed from ecology, medicine has not yet developed a common language with other sciences. The concept of "planetary health" attempts a synthesis, but remains partially integrated. Interdisciplinary collaborations (ecologists, economists, philosophers, anthropologists) are exceptional, not the norm. There is a lack of epistemic transfer models, i.e. translations between methods of measuring sustainability in ecology, economics and health. Medical discourse remains fragmented; medicine "imports" concepts, but rarely "exports" them back to the source sciences.

Temporal gap - lack of longitudinal and historical analyses. Most studies analyse sustainability over short periods (2-5 years). Few studies examine the long-term maintenance (10-20 years) of programmes or the effects of interventions. There is a lack of historical series showing how the discourse on sustainability evolves in response to crises (pandemics, climate change, conflicts). As a result, it is not possible to assess the real dynamics of institutional learning and sustainable adaptation over time.

Educational and professional gap – lack of training in sustainability. Although the term appears frequently in WHO policies and public health curricula, sustainability is not systematically integrated into medical training. Medical education rarely addresses ecology, the circular economy or resource ethics. There are no professional standards for "green clinical practice" or "sustainable decision-making". As a result, there is a disconnect between academic discourse and the reality of everyday medical practice.

Translation gap in public policy. The link between sustainability research and health policy implementation is still weak. Studies provide concepts and models, but there are no institutional mechanisms for transfer to national policies. There is a lack of knowledge brokers and policy translation frameworks to transform scientific results into sustainable regulations or clinical protocols. Sustainability often remains a declarative term, without concrete instruments for implementation.

Future research directions. Based on these gaps, several strategic directions for the development of the field can be proposed: (1) building an integrated conceptual framework of medical sustainability that includes economic, social, environmental, and ethical dimensions, (2) developing standardised tools (indices, scales, metrics) for measuring the sustainability of health interventions and systems, (3) expanding research to low- and middle-income countries to diversify cultural and institutional perspectives, (4) promoting longitudinal studies that investigate the evolution of sustainability over time, (5) creating interdisciplinary consortia between public health, ecology, economics and applied ethics, (6) integrating sustainability skills

into medical training and the evaluation of health institutions, and (7) developing science-policy translation mechanisms through centres of expertise or evidence-informed policy units.

The gap analysis highlights that, although the discourse on sustainability in academic medicine has grown significantly in volume, its theoretical depth and interdisciplinary integration remain limited. Medicine has taken up the concept of sustainability, but has not yet internalised it epistemologically. Understanding these gaps is not a criticism, but a starting point for consolidating a science of authentic medical sustainability, one that unites human health, social equity and responsibility towards the planet.

Discussions

Epistemological transition

The results indicate that between 2015 and 2025, the concept of "sustainability" underwent an epistemological transition in academic medicine. Initially used in a financial and institutional sense, the term has become a meta-analytical framework capable of integrating multiple dimensions: political, social, ecological and ethical. We can observe a shift from economics to ethics. In public health literature, "sustainability" no longer refers only to "maintaining funding", but also to , "continuity of social impact", and "ecological responsibility". Thus, academic medical discourse extends its moral domain beyond the patient to the planet.

There is an implementation of "sustainability" as a methodological core; the presence of the terms "implementation science", "quality improvement", and "programme continuation" indicates the maturation of sustainability as an object of empirical research. A technical language of measurement emerges: "sustainability indicators", "scaling-up", "fidelity", "adaptation". This professionalisation transforms sustainability into an operational construct.

The integration of the ecological dimension is another transition; after 2019, the language becomes greener. Terms such as "climate-resilient health systems", "green hospitals" and "one health" become frequent, showing a conceptual shift from economic sustainability to planetary sustainability.

The presence of terms such as "leadership", "motivation", and "attitude of health personnel" suggests a reflective approach; sustainability depends not only on policies, but also on professional values and behaviours. In this way, sustainability is integrated as a professional ethos. Academic medicine is beginning to articulate a sustainable ethos based on continuity, care and collective responsibility.

Analysis of the semantic network of PubMed literature (2015–2025) reveals that sustainability has become a polysemantic concept with five interconnected dimensions: (1) Political (sustainability as institutional resilience), (2) Operational (sustainability of implementation), (3) Social (sustainability of equity and access), (4) Ecological (planetary sustainability) and (5) Professional (sustainability of human resources). Contemporary medical discourse treats sustainability not as an outcome, but as a fundamental organisational and ethical principle that redefines the very notion of global health.

Differences in the approach to and conceptualisation of sustainability in academic medicine compared to other scientific fields

The concept of sustainability is a cross-cutting one, present in multiple fields — from environmental sciences and economics to sociology and public policy. However, analysis of medical discourse in PubMed literature (2015–2025) highlights a distinct conceptualisation that transforms sustainability from a normative ideal into an operational tool for governance and care.

The epistemological foundation translates into a normative versus operational area. In environmental sciences, sustainability is defined predominantly in ecological and normative terms. The Brundtland Report (World Commission on Environment and Development, 1987) defines it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The emphasis is on growth limits and the conservation of natural capital (Meadows et al., 1972). In economics, the approach is instrumental; sustainability means a balance between investment, resources and long-term productivity (Pearce & Turner, 1989). In sociology, the concept takes on an axiological and community-based meaning, referring to the resilience of social structures and the maintenance of social capital (Bourdieu, 1986; Putnam, 1998). In contrast, medicine develops a pragmatic and operational meaning; sustainability is defined by maintaining health outcomes and the functioning of medical systems over time, under conditions of limited resources. While other fields establish what should be sustainable, medicine investigates how health can be

maintained. This difference marks the transition from an epistemology of norms to one of action and applicability.

The object of sustainability relates to the system versus the effect. In ecology, the object of sustainability is the biosphere; in economics, the production system; in sociology, the social network. In medicine, the object is the therapeutic effect, the intervention or the health system. Sustainability is therefore linked to maintaining the effectiveness and continuity of medical services, not to the overall stability of an ecosystem. This results-oriented pragmatism gives medicine a functional vocabulary: "programme continuation", "sustained effect", "long-term implementation", and "resilience" are terms that are almost non-existent in classical economics or pure ecology.

The differences in temporality highlight the distinct orientation of medicine. In environmental sciences, sustainability is thought of in terms of centuries, on a planetary scale. In economics, time is cyclical (growth–crisis–recovery). In sociology, time is historical and cultural. In medicine, the horizon is intermediate and programmatic, from funding cycles (3–5 years) to generational impact (10–20 years). Therefore, in medical language, sustainability means maintaining functionality and efficiency within a realistic time frame, not ecological permanence.

The ethical dimension ranges from ecocentrism to the ethics of care. In environmental sciences, sustainability has an ecocentrism basis, focused on protecting nature as an intrinsic value (Leopold, 1949; Naess, 1973). In economics, ethics is utilitarian, oriented towards maximising intergenerational benefits (Solow, 1993). In sociology, sustainability has a relational component, based on cohesion and social justice (Raworth, 2018). In medicine, however, sustainability becomes an extension of the ethics of care, a responsibility towards patients, the community and professionals. This form of ethics is practical and relational, aiming to maintain health without exhausting the human, moral and ecological resources of the system (Tronto, 1993; Pellegrino & Thomasma, 1993).

Language and metrics capture sustainability as a measurable performance. While ecology uses indicators such as "biodiversity index" or "carbon footprint", economics operates with "growth rate" and "resource efficiency", and sociology with "social cohesion" and "equity index", medicine introduces operational performance indicators: "programme sustainability index", "continuation rate", "health system resilience", "patient outcome durability". This technical language reflects an evaluative and applied approach to sustainability. Instead of ideals, medicine generates measurement methods and audit criteria.

We can observe a series of recent interdisciplinary convergences. After 2020, disciplinary boundaries are becoming porous. The concept of "planetary health" (Whitmee et al., 2015) connects human health with ecosystem stability, while "One Health" links human medicine, veterinary medicine and ecology in an integrative model. Thus, medical discourse borrows elements from ecology and sociology, but translates them into terms of implementation and action: green hospitals, decarbonisation policies, climate resilience of health systems. Even in these syntheses, medicine retains its specificity: a pragmatic and interventionist orientation, transforming sustainability into a set of institutional and clinical strategies.

A comparative overview of how sustainability is operated in various sciences is presented in Table 2.

Dimension	Environmental sciences	Economics	Sociology	Medicine
Subject	Biosphere, ecosystems	Economic system	Social structures	Health, health systems
Type of rationality	Ecological	Economic	Cultural	Pragmatic and clinical
Purpose	Conservation	Efficiency	Social cohesion	Health continuity
Temporality	Long (generational)	Cyclical	Historical	Medium (programmatic)
Level of analysis	Planetary	National / global	Community	Institutional and human
Dominant ethics	Ecocentric	Utilitarian	Relational	Care ethics

Table 2: How sustainability is operationalized in different sciences

Compared to other sciences, medicine transforms sustainability from a moral ideal into an operational practice. It combines scientific rationality, care ethics and evidence-based governance to create a results-oriented model of sustainability: maintained health, resilient institutions, protected professionals and reduced

environmental impact. In this sense, sustainability in academic medicine is less a promise and more a continuous exercise in balancing healing, resources, and responsibility.

Implications for policy and medical practice

The differences in the conceptualisation of sustainability between medicine and other sciences offer not only a theoretical perspective but also practical guidelines for health governance, medical education and interdisciplinary research. Medicine, by its applied nature, transforms concepts into institutional mechanisms and professional behaviours, making sustainability a criterion for performance and social responsibility.

Health governance is beginning to move from resilience to systemic sustainability. Health policies must integrate sustainability not only as a financial or environmental objective, but as a dimension of structural governance. The resilience of health systems should be measured by their ability to maintain service continuity during crises (health, climate or economic). Sustainable financing requires not only economic efficiency, but also intergenerational equity and environmental responsibility (World Bank, 2021). Health institutions can adopt principles of "adaptive governance", in which strategic decisions include analysis of social and environmental impact. Sustainability therefore becomes an indicator of institutional performance, as important as avoidable mortality or universal access to services.

Medical education and training is moving towards a path defined by the cultivation of an ethic of sustainable care. Medical education should include sustainability skills such as environmental literacy (the impact of medical practices on the environment), resource ethics (the responsible use of technologies and medicines) and professional resilience and burnout prevention. Fostering a 'culture of sustainability' among healthcare professionals requires integrating the economic, ecological and moral dimensions of clinical practice. As argued by Pellegrino and Thomasma(1993), medical virtue includes not only competence but also continuity of care, a form of moral sustainability.

Evidence-based research and policies must include sustainability as an evaluation variable. In medical research, sustainability must be treated as a cross-cutting evaluation dimension. In implementation studies, the maintenance of intervention effects after funding has ended must be analysed (Moore et al., 2017). In public health studies, ecological indicators (emissions, energy consumption, medical waste) must be integrated into impact assessments. In global epidemiology, research on the social determinants of sustainability (education, equity, community participation) can guide inclusion policies. Thus, sustainability becomes an epistemic dimension, a criterion for scientific validation, not just an ethical goal.

Infrastructure and clinical practices will follow the transition to green systems. Hospitals and medical centres can adopt an integrated model of "green healthcare" based on energy efficiency and renewable sources, circular waste management, sustainable public procurement and digital technologies to reduce transport and consumption. According to the World Health Organisation's (2019) and the Global Green and Healthy Hospitals (GGHH) initiative, these measures reduce costs and improve the quality of care. In addition, they align medicine with the ecological ethics of the 21st century, in which human and planetary health are inseparable (Whitmee et al., 2015).

The implications for public policy result from an integrative paradigm approach. For policymakers, the results of this analysis suggest that sustainability should be treated not as an additional dimension, but as a cross-cutting axis of health policies. Public policies can be rethought on three interdependent pillars: social sustainability (equitable access, community participation), institutional sustainability (efficiency, resilience and adaptive innovation) and ecological sustainability (reducing the carbon footprint and integrating planetary health). This integrative approach responds to the need for "planetary governance for health" (Kickbusch & Gleicher, 2011), in which medicine becomes an active player in the transition to global sustainability.

While environmental sciences and economics define sustainability as balance, medicine redefines it as a dynamic process of care, adaptation and continuity. In a world subject to climatic, demographic and technological pressures, medical sustainability is no longer just an ideal, but an imperative for ethical and institutional survival. The future of public health depends on the ability of medical systems to become resilient, equitable and environmentally responsible, that is, truly sustainable.

The relevance and value of interdisciplinary analysis of the discourse on sustainability in academic medicine

The scientific importance of the analysis. The bibliometric and semantic analysis of the discourse on sustainability in medical literature provides a conceptual map of the epistemological evolution of the field. It is important because it clarifies how medicine adopts and transforms global concepts. Terms such as

"resilience", "planetary health" or "implementation sustainability" come from other sciences (ecology, management, sociology) and are "resemantized" (takes on another meaning, especially for medicine) in medical language. The analysis shows how medicine is building its own lexicon of sustainability, from ethical ideals to operational indicators. This approach connects the levels of scientific discourse; VOSviewer maps allow the simultaneous visualisation of micro (clinical practices), meso (institutions) and macro (global policies) discourse, offering an integrative perspective rarely found in public health studies. At the same time, the analysis identifies emerging trends in medical knowledge. The lexical growth of the terms "climate change", "planetary health", "equity" and "implementation science" after 2019 indicates the emergence of a new paradigm of sustainable medicine, oriented towards the interdependence between human, social and ecological health.

This analysis brings a series of innovative theoretical and methodological contributions; it redefines sustainability as a medical phenomenon and proposes a meta-linguistic reading of contemporary medicine. While most studies treat sustainability as a dimension of public policy, here it is conceptualised as an internal process of medicine, affecting the way interventions, systems and professional training are designed. Through lexical analysis and term clustering, the research reveals how meaning is scientifically constructed, not just what is said about sustainability. Thus, the contribution is not only empirical but also epistemological. Finally, this approach introduces an interdisciplinary framework for interpretation. Combining perspectives from environmental science, economics and care ethics, the study provides a model for understanding the interconnection of fields in a common semantic space.

An area of practical and applied utility can also be outlined; the results can be used in several directions. For health policy planners, the analysis provides an empirical basis for the design of integrated policies that include the social, ecological and institutional dimensions of sustainability. For example, the integration of "health system resilience" and "carbon neutrality" indicators into national performance assessments. For medical institutions, semantic maps can be used for strategic self-assessment, identifying knowledge gaps (e.g. lack of ecological or equity approaches in local research). For university and continuing education, the analysis can guide the development of transdisciplinary curricula (e.g. "Health and Sustainability", "Ethics and Green Transition in Medicine").

For research, co-occurrence maps can guide new projects such as the development of standard medical sustainability indicators, international comparative studies, and the assessment of the ecological impact of health services.

Interdisciplinary knowledge transfer is proven by this method. The transfer of concepts between disciplines is achieved through triple epistemic mechanisms. We have a terminological translation (concepts born in other fields, such as "resilience" in ecology, "efficiency" in economics or "equity" in sociology). Through this mechanism, a series of concepts are re-semanticised in medical language to describe system phenomena, implementation or professional behaviour. For example, "resilience" becomes "the ability of hospitals to maintain their functions during pandemics". Methodological transposition involves analytical tools (e.g., "systems thinking", "scenario modelling", "life-cycle assessment") that are adapted for the evaluation of medical programmes, creating new approaches such as "implementation sustainability models". The normative trans-disciplinarity of ecological and social values (responsibility, equity, intergenerational justice) is achieved through integration into medical ethics and health governance. Thus, medicine becomes not only a beneficiary but also a generator of sustainable knowledge.

These transfer processes generate a common language of sustainability, an epistemic space in which doctors, economists, sociologists and ecologists can collaborate without losing their disciplinary specificity.

The impact on the future of medicine can be significant. Such an analysis provides medicine with a reflexive framework; it allows professionals and institutions to see how they think about the future and how they build their global responsibility. Sustainability becomes, in this sense, a form of anticipatory knowledge, a science of duration, balance and continuous care. By understanding its own language, medicine can consolidate its central role in planetary health governance.

The importance of such an analysis lies in its ability to map contemporary medical discourse, reveal the internal logic of the evolution of concepts, and connect medicine with other areas of sustainable knowledge. In a world marked by health, climate and ethical crises, understanding how medicine talks about sustainability is the first step towards transforming this talk into systemic action. The essential contribution is precisely the transformation of language into an instrument of change.

Conclusions

The bibliometric and semantic analysis of medical literature on sustainability (2015–2025) shows that academic medicine has become a central player in redefining this global concept, transforming it from an ethical-ecological ideal into an operational framework for health practice and governance.

The evolution of medical discourse on sustainability. Within a decade, the term "sustainability" has moved from the language of international policy (SDGs, sustainable financing) to the internal vocabulary of medicine. Medical discourse has begun to include dimensions such as the institutional resilience of health systems, the continuity of intervention implementation, social equity and universal access, the ecological responsibility of medical infrastructures, and the professional sustainability of medical staff. This semantic expansion demonstrates the maturation of a medical paradigm that no longer separates health from its social and environmental context, but treats them as interdependent elements of a living system.

The specificity of medicine in the interdisciplinary landscape. Compared to other fields (ecology, economics, sociology), medicine offers a pragmatic and integrative approach to sustainability: it does not theorise balance, but measures continuity; it does not seek only to conserve resources, but to maintain care capacity; it does not limit itself to adaptation, but transforms sustainability into a clinical, institutional and ethical tool. Medicine thus becomes a discipline that requires translation, capable of importing concepts from other sciences (resilience, efficiency, equity, social capital) and transforming them into practices of governance and sustainable care.

Gaps and challenges. Although the volume of literature is considerable, important gaps remain: the lack of a unified conceptual framework for medical sustainability, the absence of standardised metrics and longitudinal studies, the underrepresentation of the ecological and planetary dimensions, geographical imbalance in favour of high-income countries, and poor interdisciplinary integration with environmental and social sciences. These limitations point to the need for theoretical reconstruction and international collaborative infrastructures capable of harmonising the languages and methods of sustainability in health.

Implications for the future. The results suggest that sustainability should be viewed not as an "addition" to health, but as a new way of understanding health itself. This implies a epistemological transition: from "healthcare systems" to "sustainable health systems", from "public health" to "planetary health", and from "ethics of treatment" to "ethics of care and continuity". In the next decade, the success of health systems will be measured not only by medical indicators, but by their ability to be sustainable — socially, ecologically and morally.

This research confirms that sustainability has become the new language of convergence in contemporary medicine. It is no longer just a subject of study, but a paradigm of responsibility: responsibility towards the patient (effectiveness and continuity), towards society (equity and inclusion) and towards the planet (ecological impact and intergenerational ethics). In essence, sustainable medicine is a science of duration and care, a discipline that combines healing with the preservation of life in all its forms — biological, social and planetary.

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