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EDITED BY
Ruhollah Taghizadeh,
University of Tübingen, Germany

REVIEWED BY
Pengshuai Shao,
Binzhou University, China
Jacynthe Dessureault-Rompré,
Laval University, Canada

*CORRESPONDENCE
Sabine Grunwald
sabgru@ufl.edu

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A 360° perspective of women in soil science focused on the U.S

Sabine Grunwald[1]* and Samira Daroub[2]

[1]Pedometrics, Landscape Analysis, and Geographic Information Systems (GIS) Laboratory, Department of Soil, Water and Ecosystem Sciences, University of Florida, Gainesville, FL, United States, [2]Department of Soil, Water and Ecosystem Sciences, Everglades Research and Education Center, University of Florida, Belle Glade, FL, United States

Gender parity and equity concerns in soil science have been reported in the United States and at global scale. Long-standing biases and gender stereotypes have discouraged women away from science, technology, engineering, and mathematics (STEM) research in particular soil science. However, it has been recognized that science and gender equality are essential to ensure sustainable development as highlighted by the United Nations Educational, Scientific and Cultural Organization (UNESCO). Gender equity is part of diversity, equity, and inclusivity (DEI) initiatives in higher education and professional soil science organizations in the U.S. and elsewhere. In this article we aim to provide a holistic 360° perspective of women and soils addressing gender parity, equality, and equity in the soil science profession focused on the U.S. Our critical analysis is grounded in Integral theory that considers 1) systemic institutional, organizational, educational, legal, social, political, and other system phenomena (collective perspective), 2) historical and cultural phenomena such as people's values, beliefs, motivations, communications, traditions, memes, morals, and ethics (interpersonal perspective), and 3) individual psycho-spiritual attitudes, stories, personal voices, emotions, and experiences (subjective intrapersonal perspective). This paper provides a critical review of the issues and barriers confronting women researchers, teachers, and professionals in soil science in the U.S. complemented by examples from around the globe. Concluding remarks present future perspectives of women and soils that include leadership training, mentoring for change, personal development of women soil scientists, and participation that co-creates gender parity, equity, and equality in the soil science profession.

KEYWORDS

women, soil science, gender, equity, equality, parity, soils

1 Introduction

Gender parity and equity concerns in soil science have been reported in the United States (1, 2) and at global scales (3). Gender parity focuses on statistical indicators used to describe ratios between men and women, while gender equity is the provision of fairness and justice in the distribution of benefits and responsibilities between women, men, and all genders. Gender equity implies to respect all people without discrimination irrespective of gender and address gender inequalities that limit a person's ability to access opportunities to achieve

better education and social and economic opportunities, for example to build a professional career in soil science.

According to Dawson et al. (3), soil science has been, and still is, a male-dominated discipline in most regions around the globe with current gender percent ratios of male to female as 60/40 in Africa, 78/22 in Asia, 62/38 in Europe, 64/36 in Latin America, 69/31 in North America, and 74/26 in Oceania, respectively. In total, 37 of 44 national professional soil science societies had more male members than female based on global statistical data. Overall, only about 1/3 of all soil science society members were women. These numbers point to the broader and systemic issue of gender[1] inequities in soil science, for example in soil health, soil security, and pedometrics. Gender inequities in soil science include underrepresentation of women in leadership roles and decision making, gender salary gap, promotional barriers, institutionalized gender biases, and cultural implicit biases related to gender and sex. Although women increasingly earn Master and Ph.D. degrees in soil science and science, technology, engineering, and mathematics (STEM) disciplines (1, 4, 5) suggesting a shift toward gender parity in higher education, this shift has not yet achieved full gender parity in academia, professional organizations, and private industry for soil science. Kamau et al. (6) reported on the underrepresentation of female soil and land use scientists in scientific systems (e.g., research publications) that lack gender parity and diversity especially in the Global South with socio-economically disadvantaged and developing countries. Women's underrepresentation in STEM has been attributed to lower social capital (e.g., support networks) limiting women's opportunities to earn tenure, scientific collaboration, and promotional opportunities. Gender bias in faculty hiring remains endemic in STEM disciplines with women scoring lower than men in research productivity and research impact but higher than men in contributions to diversity (7). Women faculty in STEM disciplines may perceive their academic climate as unwelcoming and even threatening due to covert and overt discrimination resembling a hostile work environment (8). Women's sense of not belonging in STEM has been attributed to "chilly academic and masculine climates" according to Casad et al. (8) and Minnotte and Pedersen (9). However, statistical and empirical data provide only partial understanding of women's relationship with soils research and education. To look beyond numbers calls for an approach that is more comprehensive and considers cultural, social, individual, and human well-being dimensions (10). According to the global perspective of the United Nations Educational, Scientific and Cultural Organization (UNESCO) (11), all forms of discrimination based on gender are violations of human rights that are significant barriers to the achievement of the 2030 Agenda for Sustainable Development and its 17 global Sustainable Development Goals. Among these goals are 'life on land' (goal No. 15) which focuses on the protection, restoration, and promotion of sustainable use of terrestrial ecosystems combating land and soil degradation. The advocation for UNESCO's gender equality implies equal rights, opportunities, and responsibilities for people irrespective of their gender (e.g., making it legal for women to own land), while gender equity emphasizes to correct historical and social injustices that have left women behind.

Gender equity is part of diversity, equity, and inclusivity (DEI) initiatives in higher education soil science curricula and research and professional soil science organizations in the U.S. and elsewhere. Delap (12) pointed out that although the global feminism movement has enacted gender equality laws in many countries and institutions, it does not necessarily mean that equality has been completely achieved in a given culture. Dean (13) pointed out the frustration of many women in which they had to deny their feminine identity to professionality succeed and "failures" of rights to secure gender equality due to pervasive hierarchies of power, sex, and gender pervading cultures and institutions.

Gender equality, equity, and parity issues and barriers women have faced in the soil science profession are critically analyzed in this paper. We endeavor to provide a holistic 360° perspective of women and soils grounded in Integral theory (14, 15) that considers 1) systemic institutional, organizational, educational, legal, social, political and other system phenomena ("ITS" objective collective perspective), 2) cultural phenomena such as people's values, beliefs, motivations, communications, traditions, memes, morals, and ethics ("WE" interpersonal perspective), and 3) individual psycho-spiritual attitudes, stories, personal voices, emotions, and experiences ("I" subjective intrapersonal perspective). The 360° integral multi-perspectival framework was applied to soil security by Grunwald et al. (16) and Grunwald et al. (17). A critical discussion in this article will examine women's participation in soil science disciplines as well as barriers, limitations, and/or marginalization they have experienced. The discussion focuses on women in soil science in the United States with additional examples from around the globe.

2 A 360° perspective of women and soils

2.1 Women and soils viewed through the collective lens of systemic institutional and organizational barriers

2.1.1 Underrepresentation of women in soil science

Women in academic leadership capacities are embedded within institutions that, by and large, were created without their input (18). Power structures in the academy have numerically underrepresented women with pronounced self-perpetuating gender imbalances that are a global phenomenon (19), especially in soil science (3). This gendered nature of soil science institutions and organizations has been a persistent stronghold that defines gender roles. This compartmentalism has inflicted both covert and overt gender biases onto female soil scientists, in turn imposing various barriers to promotions and upward movement on the soil science career ladder. Gender division also institutionalizes a professional glass

1 The authors of this article are aware that gender is more than polar opposites with a spectrum of many different genders. Gender refers to the socially constructed roles, behavior, expressions, and identities of gender diverse people. Gender is cultural and relates to society's idea of what it means to be a woman, man, neither or a mix of many genders. Gender refers to masculine, feminine, or other gender expressions, while sex refers to the biological categorization as female or male as expressed by chromosomes and organs.

ceiling for woman scientists that paints a picture in which women soil scientists are judged against; a social construct created predominantly by men in positions of power in educational, research, technological, agricultural, economic, social, legal, and other systems.

In the U.S. in 2019 the Soil Science Society of America (SSSA) membership ratio between men:women was 68:38, the SSSA committee leadership 81:19, SSSA division chairs 65:35, invited speakers at SSSA sessions 76:16, editorial representation on SSSA journals 69:23, and SSSA Fellows 83:17 [Figure 1 (20)]. Although these gender ratios have slightly tightened over the past decade only a small proportion of women are found in SSSA leadership position and awarded the prestigious SSSA Fellow Awards. These gender ratios in the soil science profession in America do not resemble the males: females 50:50 ratio in the general population in the United States according to the U.S. Census, which especially in leadership positions and Fellow Awards would be in line with parity and equality criteria. The U.S. gender ratios in the soil science profession mirror the underrepresentation of women compared to men at global scale as reported by Dawson et al. (3).

Gender-specific data and statistics allow to identify if there are gender-specific biases in a population or profession and assess if gender equality and parity have been met. Equality refers to the state of being equal, especially in status, rights, and opportunities (e.g., SSSA Fellow Awards). Parity is defined as the state of condition of being equal, especially regarding status and pay. The statistical metric that expresses if a dataset (e.g., a sample population) is equal or not is the median (50:50 split of a dataset). From statistical and DEI perspectives a 50:50 female:male ratio for measured categories shown in Figure 1 can be considered a visionary goal. In the U.S. the Equal Rights Amendment from 1972 guarantees equality for women and men. However, this amendment to the U.S. Constitution has not been ratified in all states in the U.S. The legal gender equality differs from socio-cultural (e.g., culture in the soil science education, research, and extension communities) and personal perceived equality and parity that will be discussed in detail in section 2.3.

The underrepresentation of women faculty members in academic STEM disciplines persists due to the organizational climate that entails work practices, policies, and institutional structures (21). In Settle et al.'s (21) empirical study of 208 women scientists and faculty, the *deficit theory* was tested which posits that women scientists have not yet achieved parity with men scientists because of structural aspects of the scientific environment that have provided them with more obstacles but fewer opportunities than men. This study found that women who experienced more sexual harassment and gender discrimination reported poorer job outcomes. A recent example is the U.S. Antarctic Program, managed by the U.S. National Science Foundation and contractors, which have ignored sexual harassment complaints from women scientist over more than two decades laughing them off and instead retaliating against women limiting their careers in sciences (22). Such examples are only the tip of the iceberg as woman soil scientists and students at universities have experienced similar sexual harassment and intimidations when engaged in soil mapping or field work (personal communications in a workgroup meeting on gender issues at the World Congress of Soil Science, Glasgow, Scotland, 2022).

2.1.2 Theories aiming to explain collective gender differences in the academy and disciplines

The deficit theory asserts that social, legal, and political structural obstacles in institutions exist that disadvantage women in scientific careers (23). Asymmetrical power structures in academia are still prominent at many institutions that favor autocratic and male leadership at top administrative and management levels and tends to assign moral authority and decision-making power to men (19). Such imbalanced power structures are perpetuated by male-dominated leadership positions, irrespective of shared governance

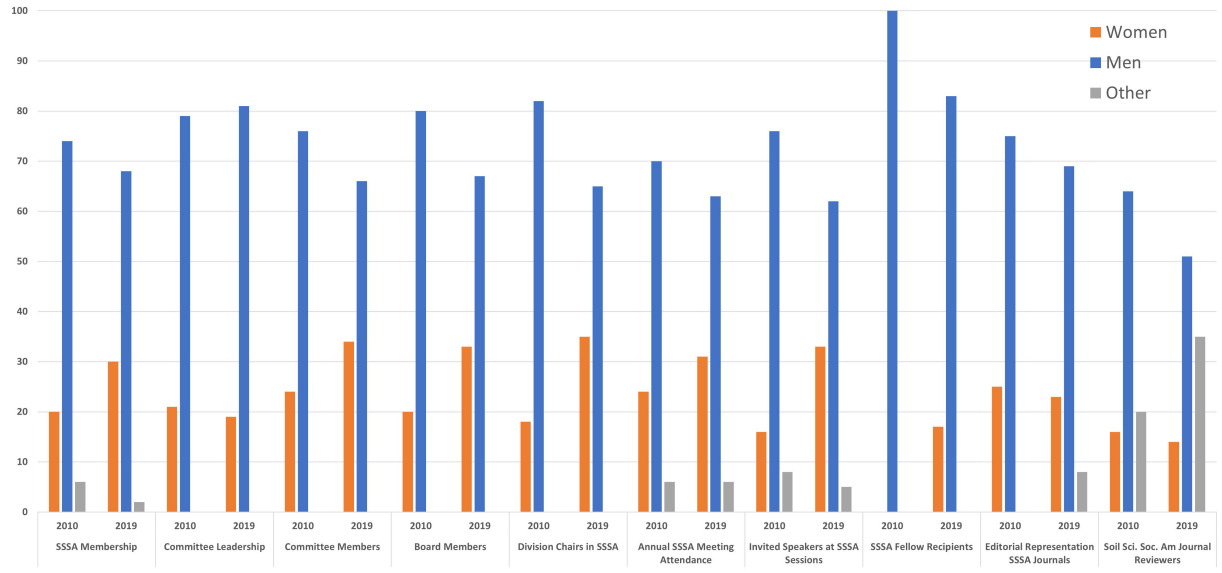

FIGURE 1
Data compiled from the "Report: Gender and the Soil Science Society of America" (source: SSSA: Soil Science Society of America. https://www.soils.org/gender/).

models, affirmative action, and lip services that too often have not become reality leaving many women disenfranchised of the privilege to lead, silenced and sidelined to be heard, treated equal to male peers, and promoted (24).

Another theory, the *difference model*, posits that deeply ingrained differences internal to individuals in behavior, outlook, and goals that exist between women and men are the root cause of gender disparities in career achievements (23). These gender differences are assumed to be innate or the result of gender-role socialization or cultural patterns (e.g., patriarchal cultural patterns) in which women need to masculinize themselves to succeed professionally (e.g., literally, wear a suit and tie and speak in an assertive voice). Riffle et al. (25) observed "unspoken" disparate valuation of the work of men and women although men and women are equally productive, women report that their departments perceive them as less productive than men. Furthermore, women believe they have less influence on, and experience less collegiality in their departments than men. Women also perceive more sexism and discrimination than men (25). The devaluation of women in science manifests in many different ways involving micro- and macro-aggressions (24), mansplaining, i.e., the tendency of some men to explain something to a woman in a condescending, demeaning, overconfident, and often inaccurate manner (26). Additionally, flexibility and caregiving needs are a part of life, but STEM workers perceived as needing flexible work arrangements are devalued and stigmatized (27).

2.1.3 Institutional barriers and biases

Traditionally underrepresented groups in particular—women and minority scholars—find their novel contributions are not uniformly adopted by others. In addition, adoption depends on which group introduces the novelty. Underrepresented genders have their novel conceptual linkages discounted and receive less credit than the novel linkages presented by the dominant gender (28). In addition, novelty, and impactful novelty both reflect successful scientific careers. They offer lesser returns to the careers of women and minorities than their majority counterparts and reveal a stratified system where underrepresented groups have to innovate at higher levels to have similar levels of career likelihoods. These results suggest that the scientific careers of underrepresented groups may end prematurely or self-direct elsewhere despite their crucial role in potential discoveries and innovation. For example, Hatch et al. (29), describe why five professors of color left their academic positions. Over time, science may miss out on what could have been their truly cutting-edge research contributions, a no-win for everyone. Hofstra et al. (28) stressed the continued importance of critically evaluating and addressing biases in faculty hiring, research evaluation, and publications that may partly explain the underrepresentation of women and minorities in influential academic positions.

Specific difficulties faced by female science faculty include less professional and scientific influence and fewer opportunities to hold leadership positions (30). These leadership limitations for women in the sciences, including the soil science profession, have been labelled 'glass ceilings' and 'glass cliffs' (31), 'ice cliffs' (32), and labyrinths (33) which undergird systemic gender discrimination in the professions. The 'glass cliff' is one of the barriers women face in climbing the career ladder and obtaining leadership positions, while men often benefit from a 'glass escalator' (34). The 'glass cliff' means that women are preferentially awarded into leadership positions that are risky and precarious in organizations undergoing crisis or facing extreme resource limitations. Gender bias and lack of socio-organizational safety nets may amplify the negative professional outcomes of women facing 'glass cliffs' (31). In 'glass cliff' situations, women leaders face more scrutiny and criticism than men even when performing similar to men in their leadership positions; women also may be singled out for blame and humiliation, which ironically may promote the very inequality that women's advancement is intended to overcome (34). 'Glass ceilings' are invisible barriers that prevent women and minorities from rising to certain levels in the professional work hierarchy. For example, 'glass ceilings' in the natural resources industries in Canada have been pernicious where women represent less than 20% of the workforce in natural resources industries (e.g., forestry, soils, and mining) although they make up almost 50% of the Canadian labor force. Such underrepresentation has resulted in persistent wage gaps and absence from leadership positions (e.g., senior executives and board members) in natural resources (35). Similar 'glass ceilings' in terms of gender wage differentials was investigated in a global study with prominent 'glass ceilings' in European and Latin American countries, whereas in Asian countries no evidence of glass ceilings was found. However, 'sticky floors', discriminatory employment patterns that keeps a certain group of people at the bottom of the job scale, were more the norm (36). Gender-biased disadvantages with pronounced 'glass ceilings' were recognized for women scientists in India (37). Interestingly, in an empirical study in U.S. academia, it was found that the perceived 'glass ceiling' is thicker in the non-math-intensive life-social-behavioral sciences compared to math-intensive natural science-technology-economics fields. Among female academics, the thicker the perceived 'glass ceiling', the lower their estimated chances to become full professor (38). McGuire (31) pointed out several strategies for women to address the glass ceiling obstacle: 1) Networking, allyship, and team building to foster a sense of belonging, 2) Attitude of "excellence is nonnegotiable" from a standpoint of meritocracy, 3) Exertion of leadership in the profession, and 4) Demonstration of resilience and grace in light of genderism.

Women's professional obstacles in organizations and institutions are often due to silent biases that are culturally and socially ingrained in social systems. These roadblocks are amplified by the double, triple, and quadruple bind that women face especially in STEM disciplines (39). These double+ binds cast doubt on women's competencies and minimize or punish them more harshly than men leaders and managers irrespective of their accomplishments. In soil science, where traditional field soil sampling was considered manual labor, and thus "man's work," it carries notions that denigrate women. However, technologies (e.g., automatic soil samplers, proximal soil sensing, remote sensing, and automated equipment) have removed physical barriers for women in soil science-related subdisciplines (e.g., pedometrics).

"No-win" situations for women arise because women are often evaluated against notions of leadership that are based on men's socially constructed characteristics and masculine traits deeply ingrained in institutional cultures (40). The insidious double-bind for women is that they are disrespected (and sometimes dehumanized) regardless of whether they choose to speak like men

or women (39). The spectrum of choices of women leaders' responses of "damned-if-you-do" (e.g., becoming an alpha female that is unfeminine; the masculinization of women to speak, act, and dress like a male) and "damned-if-you-don't" (e.g., to be less than a woman or less than a person) are both painful and dooming for women seeking leadership positions (41, 42). The predicaments for women leaders in professional organizations and institutions facing double+ binds are that 1) men are considered the default competent leaders, 2) polarized masculine-feminine perceptions with institutionalized dominance in male power, 3) women face higher standards but lower rewards, 4) women are competent but not liked (e.g., silenced, shamed, or treated as invisible objects), and 5) women are stereotyped with "feminine" style associated with incompetence or less competence than men (39, 41). Within the soil science discipline, high competencies of women in soil health, pedometrics, and soil security face double+ bind limitations that gendered institutions subtly ("hidden"), covertly, or overtly impose on women. Such social constructs silence women leaders and emergent women scientists, teachers, students, and technical staff alike providing unequal professional opportunities for women (24). If institutional cultures fuel the gendered double+ bind by intersection with other systemic biases associated with race, ethnicity, socio-economic class, religion, or other barriers, they may even turn to limitations in human flourishing and well-being (43–46). Institutions with a work culture that "take a blind eye" toward gendered double+ standards may be perceived by many women as traumatic with health and well-being consequences limiting personal development (47). Empirical data showed that gender inequality has a greater adverse effect on the well-being of women in liberal than in conservative societies in a global study of 86 countries (48).

In many universities, student course evaluations play a role in tenure committee deliberations for faculty tenure applicants. Boring et al. (49) suggested that female students rated instructors they believed to be male more highly in all instances. It follows that student evaluations are systematically biased against women. Generally, female faculty of color have fared even worse (50). Huston found that women received significantly lower course evaluations than male instructors and that faculty of color received lower course evaluations than their white peers. Students, whether they realize it or not, award teachers' credibility by a method that Huston (50) calls *idiosyncrasy credits*. These credits are the number of points that an individual can deviate from the group's expectations. Her example is a comparison of 2 individuals, one a White male, and one an Asian female. The White male receives approval credits because this is what a 'normative' professor looks like. The Asian female, who has used up all her *idiosyncrasy credits* before even beginning to teach solely by virtue of her appearance which differs from the norm, is thus penalized more by the student evaluation. When university tenure committees apply too much weight to student evaluations, they are biasing their own evaluation of the tenure applicant. A recent study from Rivera et al. (51) counters the work of Boring et al. (49) and Huston (50) and suggests that women do not always receive lower ratings from students. Huston (50), while admitting that there is still debate by some, states that the majority of research confirms that student evaluations do not really reflect teaching ability but rather racial and gender bias.

2.1.4 Strategies to address systemic institutional and organizational barriers

According to Rennison (39), individual strategies to address double+ binds and gender-based discrimination entail 1) shining a light on biased and stereotypical behavior and communication that disadvantage women in the profession and have created inequitable and unequal situations, 2) mindfully self-reflect on implicit ("hidden") biases, 3) building alliances, allyships, and networks that support women to be heard and seen (and help inoculate against retaliations by male leaders and supervisors), 4) establishing a personal board of directors or external support group who can offer sage advice and authentic communication, and 5) in case of nuclear options, finding the courage to file complaints with the U.S. Equal Employment Opportunity Commission or similar country-specific entities intended to protect women's rights. In addition, professional development opportunities of future women leaders (52), work-life balance including prioritizing research and academic writing over teaching and service as well as work from passion and purpose and prioritized self-care (53), mindfulness training opportunities to de-stress and develop emotional resilience (54), and professional development of future women leaders (55) are important strategies for individual skill building and transformation. According to Minnotte & Pedersen (9), work–life balance issues are pervasive in academic contexts. Work-life tensions, which are prominent in STEM disciplines including soil science, have been attributed to a variety of factors; among them 1) conflicts between open-ended work demands and personal lives (27), 2) flexibility stigma and devaluation of women who may need more flexible work arrangements to meet family demands (27), 3) gender differences in personal qualities relevant to science, such as professional styles and goals (23).

Rennison (39) and Xie and Shauman (56) suggested applying the following institutional strategies to counter double+ binds and gender-based discrimination: 1) Comply with criminal laws and civil right codes, 2) Respond sensitively to disclosures of misconduct; be accountable and apologize, 3) Engage in regular self-studies and conduct anonymous surveys, 4) Educate leadership about the topic, 5) Be transparent about data and policy, and 6) Commit resources to address gender issues. From an institutional perspective the stakes are high to work toward gender equality and justice in soil science and related disciplines. First, moral imperatives suggest that treating all people with respect and dignity and providing equal opportunities for professional promotions irrespective of gender. Second, minimize the effects of gender, sex, and other biases that hinder human and institutional flourishing where genderism and sexism leads to indifference and apathy impacting work productivity. Third, institutional success relies on trust and motivation of employees. The intent is to avoid women leaving work environments perceived as hostile due to frustration, social isolation, a felt sense of not belonging, trauma or other detrimental mental or emotional effects. Institutional transformation toward gender diversity and equity relies on reflective solidarity and discourse of "we-together" that deconstructs gendered identities breaking through polarities of male versus female or masculine versus feminine (13). Instead 'unity-in-diversity' (e.g., 'feminine-in-diverse genders' and 'female-in-diverse sexes') invites co-creation of non-gendered and de-sexualized perceptions.

Organizations that deliberately include women in key leadership positions are more effective, balanced, and geared for long-term success according to Johnson and Smith (57). However, examination of department heads and chairs of soil science programs reveals that only 13.5% of heads or chairs are women, and women are under-represented in soil science leadership positions in general in the U.S (1). Women face many roadblocks as they progress in their careers into administrative and higher-level leadership positions. One major roadblock is lack of effective mentoring and support network among peers. Evidence consistently shows that women face far more barriers in securing mentorships than men, and when they do find a mentor, they may reap a narrower range of both professional and psychological benefits. There are several reasons why women cannot mentor women including the fewer number of women in leadership positions. Women face many varieties of bias and stereotyping, and they are more likely to be discredited as leaders. Powerful gender stereotypes exist, and women begin to accept and internalize those stereotypes, which can translate into self-doubt and even shame that discourage them from serving as mentors to early career scientists (57).

Women leading in the academy also encounter institutional barriers. Universities that invest in developing and advancing women leaders will gain key skills like mentoring, networking, negotiating, professional development, and work-life balance. Institutions are challenged to develop healthy pathways that develop women as leaders, with attention to minority scholars, which requires to address the implicit bias held by faculty and leaders regarding women in leadership positions (58). Often developing these key leadership skills fall on individual potential women leaders with minimum or no support from their institutions.

2.1.5 Amplification of gender imparity in the sciences through COVID

Preliminary evidence from a National Academies of Sciences, Engineering and Medicine (2021) (59) report indicated that the COVID-19 pandemic has negatively affected the productivity, work-life boundary setting and boundary control, networking and community building, and mental well-being of women in academic STEMM[2]. It has led to school closures and shifting caregiving responsibilities onto parents and guardians with disproportionately negative outcomes for women across all sectors. Within STEMM, collaborations have been disrupted, career progressions have been paused, and women are facing challenges associated with gendered effects of remote work conflicting with caregiving responsibilities. For women in STEMM with children or other dependent care responsibilities, many had significantly less time in the day to network and engage in collaborations because of increased nonwork tasks (60–62). Studies suggested, too, that team size has decreased during 2020 and that women's shares of first authorships, last authorships, and general representation per author group have decreased during the COVID-19 pandemic (63, 64). The NASEM report also mentioned several contextual elements that intensified the immediate effect of the COVID-19 pandemic on specific groups, including the effects of anti-Black racism, the economic recession triggered by the COVID-19 pandemic, and the sudden importance of technology-mediated interactions. On a positive note, emerging work from several nations suggests that men have started shouldering more caregiving and child-rearing duties (65–67). Whether that trend continues is yet to be evaluated.

2.2 Women and soils viewed through a cultural interpersonal lens

Cross-culturally soil and agriculture have been linked to food production and sustainable livelihoods. Historically, monolithic masculinity has been expressed in form of rigid and conventional gender expectations with clear distinction between men's (physical labor cropping fields) and women's (caretaking and family) activities in agricultural communities from a rural sociology perspective (68). Egge (69) suggested that American agriculture emerged out of an intricate gendered system with male power to own land and control soil-environmental resources. Such traditional gendered family and patriarchal community structures are found in many countries across the globe, especially in rural areas. For example, patriarchal culture with social obstacles for women claiming land ownership in India (70), gendered peasant farming in South Africa (71), and "left behind" women in the countryside of China (72). Croppenstedt et al. (73) pointed out systemic gender differences that women have faced in the global agricultural labor force which include limited or lack of 1) property rights, 2) control over resources (e.g., land and soil), 3) access to inputs, supplies, and services (e.g., fertilizer and credit), 4) social norms, and 5) education. These gender differences from the past are still reality for many women in contemporary cultures around the world, and have shaped soil, land resource, and agricultural science professions. Women in the pedometrics and soil science profession in general are embedded in cultures with polarized and gendered views limiting women's rights. Socio-cultural factors, such as gender, socio-economic status, and the under-representation of black, indigenous, and people of color (BIPOC) have been implicated in intersectionality and structural social inequities that created profound gender gaps in soil science communities to this very day (1, 3, 74). General cultural values related to gender, ethics, morals, beliefs about women, and defined gender roles are pernicious in the soil science profession. Simmons (2020) (19) stated that gender roles may assign women the following imperative attributes: to be soft and nonconfrontational, to back down when a man asserts his point of view, submission to the point of men, and to go out of one's way to assist and provide service to others.

Soil science has been described by some as one of the least diverse of fields within STEM (2, 74). Women of color experience additional barriers to participation in soil sciences than their White counterparts (2, 74, 75). Similar to other STEM fields such as the earth sciences, soil science programs at universities have placed increased emphasis on diversifying their faculty leading to an increase in the percentage of faculty that are women, although far from closing the gender gap (1). Increasing diversity of women of color in faculty positions will need dedicated efforts in education, recruitment, and retention. The National Science Foundation (2020) (4) through the National

2 STEMM: Science, Technology, Engineering, Mathematics, and Medicine. Soil science is part of STEMM.

Center for Science and Engineering Statistics provided tabulations of diversity and degree programs (Figure 2). In the Agricultural Sciences category (that includes the Soil Science discipline) women compared to men earned a similar amount of Bachelor degrees in 2008 and even more than men in 2018. However, at the Doctoral level the number of Ph.D. degrees by men were higher than those earned by women in the Agricultural Sciences category (700 Ph.D. degrees earned by men and 498 by women in 2008; 746 Ph.D. degrees earned by men and 696 by women in 2018). In the Earth Sciences category men earned more Bachelor, Master, and Doctoral degrees than women in 2008 and 2018 (Figure 2).

Soil science is subsumed within agricultural sciences as a field of study, and without enough granularity to independently assess soil science statistics, data reported here includes all agricultural sciences (4). Most notable is that total bachelor's degrees awarded in agricultural sciences have nearly doubled in the 10 years from 2008 to 2018 with women earning 57% of these bachelor's degrees. Women received greater than 50% of all agricultural bachelor's and master's in both 2008 and 2018. Lesser gains were achieved in that decade at the master's degree and doctoral degree levels; a one-third increase, and less than one quarter increase in degree awards, respectively. Although women received more agricultural doctoral degrees in 2018 (48%) than in 2008 (41%), men earned more than 50% of doctoral degrees in 2018. Interestingly, these statistics approach gender parity with the percent of women in the 2019 US population (50.1%) and the labor force (47.1%). In addressing the broader aspect of post-graduate employment, however, NSF (2020) (4) concluded that women holding academic doctoral positions in the science, engineering, and health fields combined had increased from 26.4% to 38.5% by 2019, well below gender parity with the US population. Underrepresented minorities in academia had also increased since 1999 but their share of academic positions is small, 8.9%, and not reflective of their roughly 1/3 of the US population.

Women and minority scholars have historically experienced firsthand many injustices attributed in part to being seen through the lens of a majority male culture. Berhe et al. (2022) (75) referred to these injustices as unequal, vicious, and hostile obstacles to success. Having experienced these unjust obstacles, women and minority scholars have earned the right to redirect these historical cultural tendencies and make the academic environment for marginalized students less isolating; and more importantly, to examine the social construct and ethical foundations that produced the obstacles and to adjust practices to support success. Women can encourage *rightful presence* (76), a way to foster a sense of belonging, something that women and minority students and scholars in particular may need to succeed. *Rightful presence* allows space for diverse experiences, perspectives, and identities of all students. Key strategies for inclusive and *rightful presence* include: 1) recognizing stereotypes and appreciating individual differences, 2) displaying diversity-promoting attitudes and behaviors, 3) deliberately working to enhance cross-cultural competencies, 4) establishing trust, and 5) promoting secondary relationships and mentoring (77). Institutions need to adjust admissions, hiring, and tenure procedures so that all students see themselves reflected in the department and faculty ranks. For example, the University of Massachusetts is currently engaged in a multi-year effort to reduce bias in graduate geoscience admissions including removal of the Graduate Record Examinations (GRE) test requirement while emphasizing applicants' traits that correlate with student success (78).

2.3 Women and soils individual personal voices: Becoming a soil scientist and educator

As we have discussed throughout this paper, women in science have experienced something akin to the eternal affliction of Sisyphus

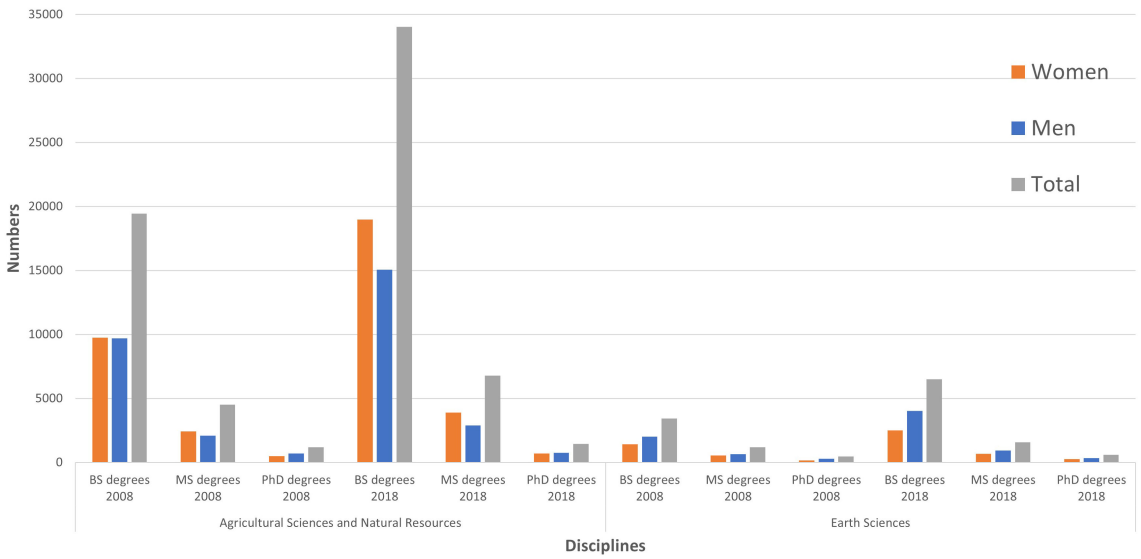

FIGURE 2
Science and engineering degrees, by race and ethnicity of recipients in the U.S.: 2008–2018. Data by field of degree and citizenship status of recipients. These categories include U.S. citizens and foreign citizens on permanent visas (i.e., resident aliens who have been admitted for permanent residency). Data retrieved from the National Center for Science and Engineering Statistics.

in just about every aspect of their daily academic work. Personal stresses are amplified for women soil scientist intersecting disparities affecting minorities. The work-life balance is something that for many years was described as 'having it all' when in effect there is no such thing. Women need to realize, regardless of their career paths, that a support network is necessary from the internal family unit to the external professional level of public agencies at the local, state and federal levels. If women were to participate equally in the job world, paid leave and family leave, affordable childcare, and flexible work hours must become staples of the working world. The COVID pandemic has shown us that flexible work is partly achievable but also has underlined the criticality of the remaining needs, as yet largely unavailable. We have learned that without these other necessities, many women are and will be lost from the workplace without sufficient personal and institutional resources.

2.3.1 Women voices

We present a few personal voices of women soil scientists randomly drawn from multiple institutions and ranks, anonymized to protect them, that speak of what it means to them of becoming and being a professional in soil science that reflect the depth of their first-hand experiences: *"I feel exhausted by being treated like I am an invisible object rather than a high achieving researcher with hundreds of publications"*, *"….my body is still shaking from another aggression by a man; gradually, these micro-aggressions have accumulated to a mountain over the years, never ending"*, *"it seems hopeless that this deeply gendered university culture will ever change"*, *"the good-old-guys sticking together and I have been left out again to participate in this soil research project/proposal"*, *"……very discouraging to see how easily white men are promoted into leadership positions, while we have to prove ourselves endlessly to be noticed and appreciated"*, *"I do strongly believe that when there are no religion repressing women, women are free and strong. I am a woman in soil science, I am a university professor and I find it very stimulating and rewarding to work both with men and women. I always had men as professional mentors, and I am working mainly with men collaborators, men farmers and men from the industry sector. I always felt respected and considered as equal"*, *"my male boss tends to mansplain and makes authoritatively decisions about my soil science research projects on my behalf like I do not exist; as a female faculty member in the department I feel treated like a second class member. The worse is that if I question such bigotry I, the woman faculty member, am ignored or blamed for it, like I am making things up, and face retribution and repercussions that limit my professional success"*, *"…. implicit gender bias shows up in many ways, for example, administrative lip service about DEI*[3] *that stands in stark contrast to how women soil scientists are treated compared to males in the profession"*; *"… my white male boss denied again that there is a gender salary gap, though the salary data for male and female faculty members in the department show otherwise; statistical data are real"*.

Personal voices are deeply experiential, visceral, and individual. We invite readers to honor and hear them. To question these women voices as angry, fake, delusional, or "over-the-top" would be what psychologist call "blaming the victim". Devaluing women's experiences and blaming them in whole or part for their experience as a human being, intents to deflect from the core issues of perceived gender-based inequity, inequality, and imparity. The strategy of blaming the victim serves to distance themselves from an unpleasant occurrence that feels uncomfortable, and attempts to rationalize that the real problem is with the woman (the other person), not with them (the aggressor) or a culture or institution that does not recognize women as equal and deserving as others. Importantly, the aggressor may be conscious or not even aware of harming and victimizing a woman.[4] The double bind for women is in institutions and organizations that have implemented gender-based DEI policies and/or human resources regulations, though within the organizational culture or in professional relations implicit biases against women prevail.

The non-acceptance of personal women's voices that are labeled as angry and negative stand in contrast to the compelling gender-specific data and statistics, cited publications in this paper, and documented women's experiences in the soil science profession. Noteworthy is that the literature on this topic as presented in this paper unequivocally concurs that a substantial number of women in soil science have experienced, or even been traumatized, by repeated perceived gender-based non-parity, inequity, and inequality in the profession. This does not mean that all women in soil science have suffered from gender-based issues. However, the aversion to accepting, or at least tolerating, personal women's experiences as real to them may lead to re-victimizing or re-traumatizing them.

The quotations of women's voices in the soil science profession stated above do not represent all women. There are certainly positive or neutral intrapersonal experiences of women in the profession that have occurred (e.g., joyful support from male allies and mentors; equal treatment of women and men in promotions and salary increases; celebrations of leadership awards for exceptional high-performing women soil scientists). Though according to the statistical data reported in this paper gender parity, equity, and equality have not been fully realized in the U.S. and elsewhere, which suggests that inequalities are still prevalent in the profession and are lived reality in relationships. In response to this, some women may not mind being treated differently such as receiving less awards, salary, and recognition ("ignorance of gendered treatment"), rationalize away gender-based inequalities ("gender blindness"), demonstrate acceptance ("gender-based inequalities is how it is and will be"), or experience resignation ("silent women"). In other cases, women may show indifference or passivity toward gender-based imparity ("women without voice"), or even feel anxious and fearful to talk about gender ("silenced women"). To reframe and realize the vision of gender-based DEI at the intra- and interpersonal level inherently involves raising awareness of gender-based issues in the soil science profession and invites dialogue that eventually transforms the experienced relations as equal, co-creates culture that is gender aware (policies and morals), and creates gender aware institutions (laws and regulations). More indepth qualitative research that

3 Diversity, equity, and inclusivity.

4 Implicit bias has been identified as the mechanism that affects judgement, decisions, and behavior. Implicit bias occurs automatically and unintentionally (see Banaji RR and AG Greenwald. Blindspot: Hidden biases of good people. Bantam Books, New York, NY0).

investigates women's experiences in the soil science profession and education is needed.

2.3.2 One woman's voice

In personal narrative form, voice is given to becoming a leader in the soil science academic profession: "*When I moved from my professor position into administration at a US university, some people congratulated me, and others said 'condolences'. I often reflect on my journey, the challenges, and the implicit bias I faced as a female student of soil science, faculty member, and now an administrator. It was not an easy journey, but I was not alone on this journey. I 'leaned' into many mentors, both men and women, who were allies and sponsors. My first mentors were my parents who gave me confidence* in *my abilities. I do not know if they were aware of it, but their love, support, and belief that all their children were extraordinary, gave me the courage to move to the US to pursue my studies. When I earned my doctorate degree, my PhD advisor, a White man, believed strongly in my abilities that he entrusted me to run his research lab and teach his graduate classes as he became department chair. His trust and belief in my abilities propelled me in my professional journey. During my faculty journey, I became aware of the lack of opportunities to advance my career, implicit bias and microaggressions from others including people in leadership positions. I began to develop my formal leadership and administrative training after I was promoted to full professor, and I became more involved in college and national society service. I took advantage of faculty advancement opportunities at my university for leadership training for land grant universities future leaders. I sought these opportunities and advocated for myself with administration to be nominated and costs covered. In my administration role, I am acutely aware of my responsibility to recruit, mentor, and foster an inclusive environment for women faculty and faculty from underrepresented groups. I am also aware that I need more than ever a network of mentors including peers, allies, and sponsors to be successful and effective.*"

2.3.3 Women soil scientists as role models

Woman soil scientists who achieved extraordinary achievements in the profession serve as role models for the future generation. Dr. Laura Bertha Reyes Sánchez from Mexico was the President of the International Union of Soil Sciences (IUSS) from 2021-2022 serving as leader of the global community of soil scientists. In the USA, Dr. April L. Ulery, Dr. Mary Collins, and Dr. Carolyn Olson served and Dr. Carrie Laboski currently serves as President of SSSA, among the few women soil scientists who achieved this recognition. Dr. Cynthia Rosenzweig stands out as a woman scientist who achieved extraordinary success as a transdisciplinary leader (climate, crops, food, and soils). She was awarded the World Food Prize in 2022 based on her extraordinary research achievements in the study of climate impacts on soils and crops as a Senior Research Scientist at the NASA Goddard Institute for Space Studies, where she heads the Climate Impacts Group. She is a Professor at Barnard College and a Senior Research Scientist at The Earth Institute at Columbia University. She was a Coordinating Lead Author of Working Group II for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) United Nations (UN) Sustainable Development Solutions Network (SDSN) and the Campaign for an Urban Sustainability Development Goal (SDG). She was named as one of "Nature's 10: Ten People Who Mattered in 2012". In 2010 she founded the Agricultural Model Intercomparison and Improvement Project that had global impact on soil, crop, and climate research. Dr. Asmeret Asefaw Berhe, Professor and Falasco Chair in Earth Sciences at the University of California Merced has broadly focused on soil science and global change science. Recently, she was appointed Director of the Office of Science at the U.S. Department of Energy. She is an advocate for women in soil science and serves on the board of the Earth Science Women's Network and the Advisory Board of 500 Women Scientists a grassroots organization working to make science open, inclusive, and accessible.

There were also women soil scientists who broke new ground (e.g., Mary C. Baltz, 1923-2011, who was the first woman soil scientist officially assigned in field soil surveying for the U.S. Department of Agriculture, Natural Resources Conservation Service). Unsung tragic superheroes are woman soil scientists like Vera Aleksandrovna Baltz (1866–1943) who graduated with a gold medal from the St. Petersburg Alexandrovskaya female gymnasium, and then became the Director of the famous V.V. Dokuchaev Museum of Soil Science in 1920. She was accused of antigovernmental agitation by the Soviet government, imprisoned, and later died of myocarditis brought on by starvation at age 76. Every country has woman pioneers that irrespective of the historically male-dominated soil science profession achieved extraordinary recognition. For example, Ana Maria Primavesi was a well-known agronomist and soil science educator in Brazil, who provided leadership inspiring young female soil scientists that will further shape the future profession.

3 Concluding remarks: Future of 360°C women and soils

3.1 Leadership development opportunities in higher education

There are many professional development programs in the US to develop effective leadership skills, breaking the implicit bias habit, while enhancing diversity and inclusion and cultural awareness. Many US universities have in-house training programs that women faculty can take advantage of at no cost and start the journey of developing their leadership skills and leading change. National programs often require nominations from administration, are competitive to enroll in, and can be costly. One program that provides leadership and professional development training for faculty and professionals within the land-grant system is LEAD21. The University of Georgia provides the oversight and management of the program as they are contracted by the Associations of Public and Land-grant Universities (APLU). The Women in Science & Engineering Leadership Institute (WISELI) at the University of Wisconsin-Madison disseminates effective programming, resources, and measurement instruments "to increase the representation, advancement, and workplace satisfaction of women, gender minorities, and/or members of groups currently underrepresented on the faculty and in leadership at the University of Wisconsin. WISELI's workshops and materials in implicit bias and faculty

searches for excellence and diversity are offered to colleges and universities in the US and internationally. Many institutions send potential leaders to the Harvard leadership institute, an intensive two-week program (79). The Higher Education Resource Services (HERS) summer institute for women in higher education administration focuses on developing women leaders and currently has multiple program models (80). HERS was established by senior level women to address the lack of career opportunities for women in colleges and universities. Aside from referrals, support, networks, training, and professional opportunities made available through HERS, the organization also conducts and disseminates gender equity research designed to inform about issues, such as pay equity, imposter syndrome, diversity and gender equity, authentic leadership, and effective communication (80). In August 2022, the IUSS and the National Soil Science Societies approved for the first time the 'diversity, equity, and inclusive policy' which advocates for geographic distribution and gender equity, and monitoring of gender equity and geographical inclusion in leadership positions and invited speakers at IUSS events and publications.

3.2 Mentoring for change

Women can become mentoring agents of change for students as they navigate university and graduate school. Mentoring is a term used to describe an array of different kinds of relational activities between an expert and a protégé or student. Silver (2020) (52) emphasized that creating a mentoring network is the new model for effective mentorship. Good developmental relationships (mentorships) promote socialization, learning, career advancement, psychological adjustment, and preparation for leadership. Compared to unmentored individuals, those with mentors tend to be more satisfied with their careers, enjoy more promotions and higher income, report greater commitment to the organization or profession, and are more likely to mentor others in return (77), an efficient way to effect long-term cultural change. To boost the self-confidence in women life coaching has provided success (81). Executive women leadership coaching in STEM fields showed success to achieve gender balance in medical physics and biomedical fields (82), though executive coaching in soil science is rarely available to women soil scientists.

3.3 Personal development

Women soil scientist may choose from an ecology of practices to wholeheartedly embody womanhood and bring awareness to the expression of gender and femininities in different cultural and professional settings. For example, practices may entail wellness exercises or personal training workshops that foster well-being and human flourishing. Well-being includes physical, mental, emotional, and psycho-spiritual health dimensions. To explore one's own gender identity/ies and implicit biases is an important step to create gender-informed workplaces. To raise awareness about the role of gender in the soil science profession will co-create workplaces in which DEI is a lived reality rather than just a buzz word for women and other genders alike.

Practices focused on self-care and self-growth are inner directed (e.g., mindfulness meditation, journaling, paining) whereas other trainings focus on relational development (e.g., work-life balance workshops, women groups that provide safe spaces for sharing of life stories or mixed gender groups focused on dialogue). Connecting with nature, Mother Earth, or soilscapes that carry deep personal meaning invite women soil scientists to explore the meaning of soils (e.g., soil health, soil as life force, soil care, soil to sustain humanity, creation stories linked to soil and clay) (83). Personal development amplifies co-creative engagement in work environments, institutions, and cultures that are gender-sensitive and honor human rights and justice irrespective of gender orientations.

Women soil scientists who have experienced gendered stresses, for example micro-, meso-, and/or macro-aggressions at the workplace, may seek counseling and therapeutic services or private spaces for healing and recovery from trauma. Even micro-aggressions if accumulated over longer periods of time may be experienced as debilitating to mental health and well-being especially in workplace cultures that are less trauma and gender informed.

3.4 The future of women and soils

One may argue that this paper does not provide supporting empirical data in support of the perspective of gender parity and equal opportunities for women in STEMM and specifically soil science. Some statistics are available only for the aggregated agricultural sciences. Based on our findings the scholarly literature converges and confirms that genderism is prevalent in soil science as well as other STEMM disciplines. Such findings were derived through various methodologies and perspectives including statistical data, empirical studies, critical reviews in higher education and STEMM science, feminist literature as well as personal voices of women in the soil science profession.

The outlook of women in soil science has the potential to address pernicious genderism in the profession. Strategies to achieve diversity, equity, and inclusivity are not limited to gender, but include many other "isms". As a step forward it is important to form local, national, and international 'women soil science' professional workgroups and networking to speak with a unified voice, co-create allyship, and provide emotional support for women in the soil science profession. In addition, it is valuable to raise awareness about issues that women in soil science face through dialogue, data and statistics, and publications, like this one. It is of outmost importance to enhance acknowledgement at people's and organizational levels that gender imparity, discrimination, and male-female stereotyping are not only "a problem that exist in women's imagination". The reframing of gender ignorance, gender blindness, and derogatory gendered behaviors into more gender neutral or gender unified spaces in soil science would unleash motivation, creativity, and productivity; thus, elevating soil sciences. To raise awareness of implicit gender bias helps opening conversational spaces that address male-female polarities and gendered experiences that have negatively impacted the

professional careers of women and limited progress in the soil science discipline. This invites future education and research to focus not only on technical and scientific topics such as soil health, soil security, and pedometrics, but to explicitly include dialogue on gender issues and care (relational) ethics in professional trainings, curricula, and education. A guiding vision that strives for human flourishing, work-life balance, well-being, and professional success for all members in the soil science community may serve as a guidepost. Both feminine and masculine energies and principles hold importance for a flourishing soil science community. Literally deconstructing and understanding how we socially construct gendered hierarchies and apply gender constructs to bolster personal power and leadership, or gendered institutional power structures can create new momentum to elevate soil science.

Author contributions

SG, first author, thoroughly reviewed the literature and wrote substantial parts of the article. SD, second author, also reviewed the literature and wrote sections of the article. Both authors cross-fertilized the content of this article through numerous discussion meetings in Zoom. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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